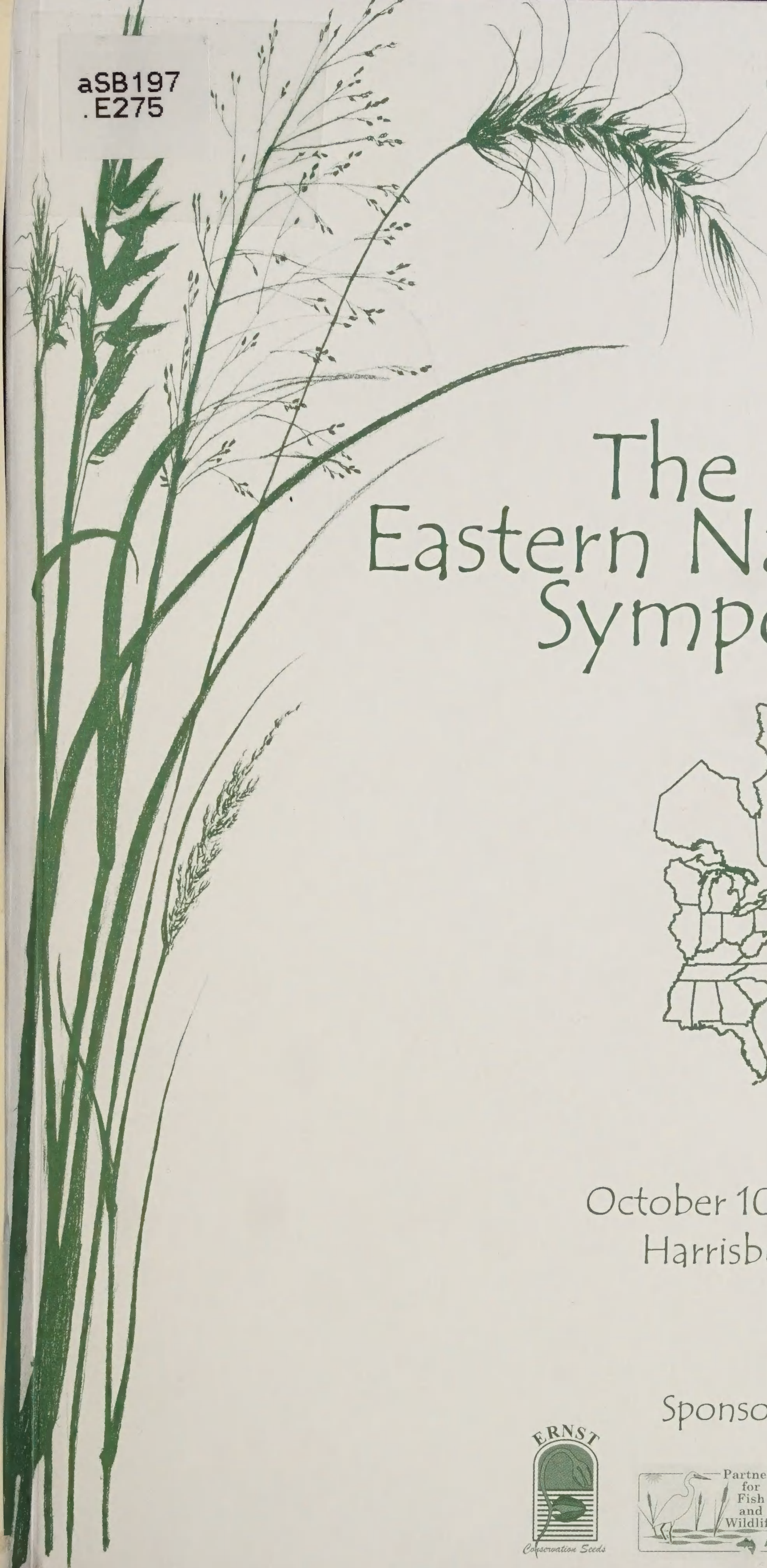

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The Fifth Eastern Native Grass Symposium

October 10-13, 2006
Harrisburg, PA

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PROCEEDINGS

OF

THE FIFTH EASTERN NATIVE GRASS SYMPOSIUM

HELD IN
HARRISBURG, PENNSYLVANIA
OCTOBER 10 -13, 2006

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Introduction

In February 1997 a one-day conference on native grasses in the Eastern United States was held at the Botanical Gardens in Asheville, North Carolina. After nearly ten years the meeting has grown into a biennial three-day symposium rotating among different locations throughout the Eastern United States. This is quite an accomplishment for an event that has no sponsoring organization. The Eastern Native Grass Symposium is sustained by the expanding interest in the subject and the devotion of a variety of people, from agency technical specialists and private consultants, to growers of seed and nursery stock, to equipment and pesticide dealers.

Presentations at the first symposium focused on native grass establishment and management for forage production and grassland restoration. This fifth symposium is made up of over 90 oral and poster presentations. Topics include biofuels and carbon sequestration, biomass, cultivar and ecotype development, establishment and weed control, forages and grazing, genetics, invasive species, reclamation and restoration, roadside management, seed harvest and processing, and wildlife management.

Beginning with the second symposium in Baltimore, Maryland in 1999, the event has included field trips and on-site workshops. This fifth symposium provides six choices for full-day field trips and three workshop subjects. The second symposium was also the first time proceedings were published. This fifth symposium is the first time the proceedings are published in advance of the symposium.

Since the symposium was last in the Mid-Atlantic region, both the knowledge and experience bases of native grass establishment in the Eastern United States have increased significantly. The best management for each of the many uses of native grasses is now a significant concern. There is a noticeable shift in the subject matter of presentations from establishment to management.

This quote from the proceedings of the second symposium is as applicable now as is it was seven years ago:

"Native grass use is expanding as rapidly as the seed and plant supplies of eastern sources will allow. The recent demand for materials is being driven by both a desire to utilize native plants to meet resource conservation objectives, and additional discovery of valuable functions which native grasses bring to discreet habitats and the environment in general. Native grasses bring a host of valuable traits to the conservation effort. Relatively unknown, under-appreciated, under-researched, and therefore under-used, native grasses will [continue to] play a powerful role in environmental improvement as use technology is developed and institutionalized."

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DEDICATION OF PROCEEDINGS

John A. Dickerson

Finger Lakes Conservation Services
Marcellus, New York

These Proceedings of the Fifth Eastern Native Grass Symposium are dedicated to John A. Dickerson, formerly Plant Materials Specialist, USDA, Natural Resources Conservation Service (retired).

John has worked to advance the knowledge of native grasses in the Eastern United States for decades. During his career with USDA, he supported the Big Flats Plant Materials Center, Big Flats, New York in collecting, evaluating, and releasing native grasses, and in assisting commercial growers with their production. John tested and developed technologies to re-vegetate sand and gravel pits in New York and throughout New England with native grasses. He continues to exchange ideas and technology on native grass establishment and management with people throughout the North American continent.

John has played a key role in all five of the Eastern Native Grass Symposiums, including Co-Chairing the second symposium. And he continues to demonstrate his leadership role by accepting responsibility to solicit a host for the Sixth Symposium to be held in 2008.

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Wildlife Management

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Biofuels

Land Use Change Effects from Cellulosic and Grain Ethanol Production under Climate Change

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Bioenergy cropping systems could help offset greenhouse gas emissions, but quantifying that offset is complex. Bioenergy crops offset carbon dioxide emissions by converting atmospheric carbon dioxide to organic carbon in crop biomass and soil, but they also emit nitrous oxide and vary in their effects on soil oxidation of methane. Growing the crops requires energy (e.g., to operate farm machinery, produce inputs such as fertilizer), and so does converting the harvested product to usable fuels. The objective of this study was to quantify all these factors and model the impact of climate change on the net effect of switchgrass (*Panicum virgatum* L.) and a corn (*Zea mays* L.) rotation on greenhouse gas emissions. We used the DAYCENT biogeochemistry model to assess soil greenhouse gas fluxes and biomass yields in Pennsylvania. DAYCENT results were combined with estimates of fossil fuels used to provide farm inputs and operate agricultural machinery and fossil fuel offsets from biomass yields to calculate net greenhouse gas fluxes for each cropping system considered. Displaced fossil fuel was the largest greenhouse gas sink followed by soil carbon sequestration. N_2O emissions were the largest greenhouse gas source. All cropping systems simulated provided net greenhouse gas sinks compared with the fossil fuel life cycle, even in the long term when there were no further increases in soil carbon sequestration. Compared with the life cycle of gasoline and diesel, ethanol and biodiesel from corn rotations reduced greenhouse gas emissions by 30-35% and over 110-120% for switchgrass.

Key words: Biofuel, carbon sequestration, greenhouse gas, switchgrass

Growth of Switchgrass as Biofuel in the Pacific Northwest

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Abstract

Switchgrass (*Panicum virgatum* L.) has been grown as a seed crop in the Pacific Northwest (PNW) for more than 20 years but monitoring for adaptability as forage or research into biomass for ethanol production had been lacking until about five years ago. During the past five years we have established eight field research studies at Paterson, WA (Quincy sand with 0.4% organic matter; 92% sand, 5.6% silt and 2.7% clay irrigated soil and Prosser, WA (Warden silt loam 1.5 to 2.5% organic matter, 2-5% slope irrigated soil irrigated evaluating switchgrass production potentials in the PNW. This paper will highlight some of our results and a few conclusions from hard-learned lessons.

Key words: Biofuel harvest, growth and development, irrigated switchgrass, varieties,

Establishment and Emergence

Switchgrass seed is naked, very small with about 325,000 seeds per pound and easy to drill. When planting a clean and firm seedbed is essential along with a drill equipped with covering chains or packing wheels to ensure good soil-seed contact for rapid germination. We have successfully established stands with seeding rates from 7 to 12 lb pure live seed per acre with a drill on 6-inch centers. Seed germination for materials we have planted has ranged from <30 to > 70% for varieties so it is important to calculate PLS and adjust equipment for planting. Weed control is a major issue during the establishment period. Several herbicide trials at Paterson show that pendimethalin applied pre or post-emergence at 0.66 to 1 lb ai per acre provides excellent control for many of our problem weeds at both locations. However, pendamethalin on these sandy soils nearly destroys the establishing switchgrass at both rates. At Prosser, pendamethalin used pre-emergence did stunt the switchgrass during the early seedling establishment stage but this lessens as plants develop. It does not provide season long control because of our irrigation methods that stimulates the weed seed bank. We have found injury differences among switchgrass varieties for post-emergence products. The herbicide mesotrione damaged both Cave-in-Rock and Shawnee varieties more than Kanlow.

Growth and Development

Switchgrass breaks dormancy from early to mid-April but has less than 6 inches of growth by May 1st. With adequate irrigation and temperature, switchgrass will be 20 inches or taller by late May in our region. With increasing June summer temperatures, growth increases significantly. The earliest maturing switchgrass variety we've grown is Dacotah, which heads by mid-June and fully headed by July 1st, several weeks before other varieties. July growth and regrowth is rapid if soil moisture is maintained. Our first biofuel biomass

harvest occurs within the first two weeks of July and crops will be about 4 to 6 ft high at that time. By leaving a 4- to 6- inch stubble at harvest, regrowth will be observed within 5 to 7 days. Growth during August is slowed compared to July, we think possibly due to photoperiod not temperature or irrigation. By September growth is much slower than in August with temperatures cooling much from the previous month. Final biofuel biomass harvest should be made in late September to early October again leaving suitable stubble for winter survival. We have not experienced winterkill with any switchgrass varieties and we believe this is due to the deep dormancy of the plant in late October to early November. We had record low temperatures in December, 2004 (-19^{0}F) when the first switchgrass planting was in the juvenile stage. All the varieties survived without problems.

Varieties

Last year we planted Alamo for the first time and stands are still very weak with an open canopy allowing for greater weed invasion than any other variety in our research. Kanlow, a lowland variety, has performed very well at both locations. Dacotah is the earliest maturing and may be too early for biofuel production in the lower Columbia Basin region. We believe Dacotah maybe best adapted to a higher elevation, shorter growing season where natural precipitation is adequate for this deeply rooted plant to survive. Other varieties evaluated include Cave-In-Rock, Trailblazer, Blackwell, Nebraska 28, Sunburst, Forestburg and Shawnee.

Production Response in the PNW

We lack the production history of growing switchgrass compared to other areas of the US where this grass is native. However, we have identified two important results. First, yields continue to increase each year as stands thicken in the initial 2002 planting managed for biofuel. Second, second year production yields were similar to those reported in the mid-west with six-year old stands.

Things We Have Learned

Switchgrass should be planted by late May to mid-June in the PNW in a well developed seedbed with early weed control to promote good stands the first year. We clipped weeds, leaving an 8-inch stubble during the establishment year without harming the switchgrass. Switchgrass produces well with a minimum level of soil nutrients and over fertilization of switchgrass stimulates weed growth. For biofuel production we harvest twice per growing season. The first harvest occurs in early to mid-July and second at the end of the season in late September or early October. Adequate stubble height is essential to sustain the crop. In a simulated pasture clipping trial last year, I though I'd killed the switchgrass by early September. It surprised us this spring by breaking dormancy, certainly later than hay or biofuel treatments. As a biomass crop managed for ethanol production with maintenance of adequate stubble, long-term survival should likely not be an issue. Switchgrass is a viable crop in the warm regions of the PNW if natural rainfall is adequate or irrigation water is applied.

The Potential for Grasses as a Feedstock in Energy Applications in the Eastern United States

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Native grasses and other herbaceous crops are the most promising renewable energy resources available to the nation at large. The development of biomass as a feedstock for use as a biofuel (ethanol) or for biopower (electricity) has been receiving a substantial amount of attention. However, the use of grasses as a feedstock for the generation of energy has been slow to develop in the United States. With the increasing costs of liquid fuels and electricity the potential to integrate biomass fuel sources is gaining momentum. The primary reason for the lack of widespread development is the lower cost of energy derived from fossil based resources like oil, natural gas, and coal.

Switchgrass (*Panicum virgatum* L.) is the native herbaceous energy crop that has received the most interest in the United States. Many other herbaceous species can also be used to produce biomass for use in power generation, liquid fuels, chemicals, and other intermediary products. These include perennials that are already established and used for forage, perennials that would have to be planted like switchgrass, and annuals that can be integrated into cropping systems with other crops. Both warm and cool-season species should be considered within each of these categories in order to facilitate a year-round supply. Unlike many other energy crops under consideration, the equipment necessary to establish, maintain, and harvest herbaceous crops is available. This technological advantage makes the rapid deployment of herbaceous feedstocks in energy applications possible. While the production of herbaceous energy crops is feasible with existing equipment the overall infrastructure and economics of commercial-scale operations is still being defined. Through the analysis of existing herbaceous forage crops, large-scale demonstrations of dedicated energy crops like switchgrass, and experimentation with innovative planting and management techniques, the true potential of herbaceous energy crops is being realized. A major obstacle to widespread use of biomass resources is the cost to transport the material from where it is grown to the conversion facility. Due to the low bulk density and energy content of biomass materials, innovative collection and processing applications have been developed to overcome these economic challenges. Field chopping, new baling and de-baling equipment, and innovative milling technologies have demonstrated the technological and economical potential of commercial-scale applications.

This paper reviews the economic potential of warm and cool-season grasses for use in energy applications in the Eastern United States. Through the use of a computer-modeling program called Switchsym, all of the inputs associated with herbaceous crop production have been captured and analyzed. A discussion of the overall economics of feedstock production, delivery and processing of native and other herbaceous crops are reviewed.

Key words: Biofuel, biopower, renewable energy, switchgrass

Potential of Native Warm-Season Grass Monocultures and Mixtures for Bioenergy in the Northern Great Plains

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High yielding, native warm-season grasses could be used as renewable bioenergy feedstocks. The objective of this study was to compare biomass production potential and chemical composition of switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon geradii* Vitman), and indiangrass (*Sorghastrum nutans* L.) monocultures to all 2- and 3-way mixtures of these species across an east-west environmental gradient. Switchgrass, indiangrass, and big bluestem were planted as monocultures and in 2- and 3-way mixtures at three locations (Morris, MN; Brookings, SD; and near Pierre, SD) during May 2002. Biomass at each location was harvested after a killing frost once annually from 2003 to 2005. A grab sample (about 2 lbs) was taken from each plot at harvest for determination of dry matter and chemical composition. Averaged across species, yields ranged from 0.72 to 3.20 tons ac^{-1} at Brookings, 1.32 to 2.20 tons ac^{-1} at Pierre, and 1.52 to 2.28 tons ac^{-1} at Morris during the three years. Yields were lowest in 2003 and highest in 2005 at each location, although they were similar at Brookings in 2004 and 2005. It is not entirely surprising that yields were lower the year after establishment than in succeeding years since these grasses often establish slowly. In addition, timely precipitation during April-May resulted in higher yields in 2005. Averaged across years, there was a species/mixture effect on biomass production at Brookings and Pierre. At both locations, monoculture switchgrass and mixtures with switchgrass had higher yields than either big bluestem or indiangrass monocultures. A similar trend was noted at Morris despite the fact that yield differences between species/mixtures were not significant. In general switchgrass was the dominant species in all mixtures in which it was present during establishment and the first year after establishment. However, by the second year after establishment, big bluestem was often the dominant species in all mixtures in which it was present. Biomass cellulose, hemicellulose, lignin, TN, and ash concentrations varied by year and location. Cellulose concentration tended to be higher in indiangrass while hemicellulose concentration tended to be higher in switchgrass. These results indicate that switchgrass, big bluestem, and indiangrass monocultures, and mixtures containing these three species, are prime candidates for use as biomass feedstocks in the northern Great Plains. While switchgrass dominated plots out-yielded the other species, mixtures of species may be more advantageous for wildlife habitat and other recreational uses. Thus, individual biomass producers may be able to plant mixtures adapted to their particular situation.

Key words: Big bluestem, biofuels, indiangrass, switchgrasss

Developing Warm-Season Grasses as a Densified Heating Fuel

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REAP-Canada (Resource Efficient Agricultural Production) has been working since 1991 on bioenergy crop production from grasses to control greenhouse gases and reduce energy demand of fossil fuels. The main focus has been on bioheat to substitute for fossil fuels. REAP-Canada was the first agency in Canada to research warm-season perennial grasses as energy crops and the first agency in the world to successfully pellet and burn densified switchgrass (*Panicum virgatum* L.) as a fuel. Pelletized grass biofuel is poised to become a major fuel source because this fuel pathway is capable of meeting some heating requirements at less cost than all available alternatives. The main advantages of this energy production approach result from:

- efficient use of low cost marginal farmland for solar energy collection
- minimal fossil fuel input use in field production and energy conversion
- minimal biomass quality upgrading which limits energy loss from the feedstock
- efficient energy conversion in advanced combustion appliances
- replacement of expensive high-grade energy forms in space and water heating
- an overall energy output to input ratio of 14:1

The main technical barriers to the development of herbaceous biomass for combustion have been optimizing biomass combustion quality, crop productivity and harvesting logistics. The main quality problem of grass is the high potassium and chlorine content which results in difficulties during combustion, including corrosion and clinker production. Late fall and spring harvesting leads to significant improvements in biomass quality by reducing potassium and chlorine content. However, over-wintering also results in major yield losses. Late fall mowing and spring baling to avoid over-wintering losses due to mechanical breakage has emerged as a possible solution. Increased understanding of delayed-harvesting practices can optimize biomass combustion quality and recoverable biomass yields. Advancing technologies to burn higher ash fuels is also advancing the use of agri-fuels for combustion. Commercialization of grass bioheat for greenhouse heating applications using commercial boilers appears to be the most attractive option due to dramatic increases in the price of conventional fossil fuels and increasing shortages of wood residue for making fuel pellets. Pellets made from moderately high ash crop milling residues (oat hulls and wheat middlings) are now being used by 24 greenhouses in Ontario for heating. Producing economical, perennial energy crops could greatly expand the fuel supply for this emerging industry and appears to minimize risks in developing this opportunity as crop milling residues are already being used in these systems. Pelletized grass biofuels can provide consumers with price stable and low-cost heat while dramatically cutting emissions, with Bioheat currently 25-50% cheaper than heating with oil or natural gas. The development of an agri-fibre biofuel pellet industry has great potential to revitalize the rural economy of North America by absorbing the surplus production

capacity of the agricultural sector and cutting on-farm fuel costs in heating intensive sectors like greenhouses.

Key words: Bioenergy, bioheat, pellettizing, switchgrass

Biofuels Research with Native Grasses at the USDA-ARS Pasture Systems and Watershed Management Research Unit, University Park, Pennsylvania

M. A. Sanderson, P. R. Adler, R. H. Skinner, and C. Dell

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www.ars.usda.gov/main/site_main.htm?modecode=19020000.

Research on switchgrass (*Panicum virgatum* L.) as a biomass energy crop is conducted at several USDA-ARS facilities across the USA. At the USDA-ARS Pasture Systems and Watershed Management Research Unit in University Park, Pennsylvania, research on biomass energy focuses on cropping systems, environmental effects, and management practices. Cropping systems research compares the biomass and energy yields of perennial [switchgrass and reed canarygrass (*Phalaris arundinacea* L.)] and annual (corn, *Zea mays* L.) components in different combinations. In addition, the biomass energy crop rotations are compared with conventional (corn-alfalfa, *Medicago sativa* L.) crop rotations, and a grazing system for carbon sequestration and greenhouse gas emissions. Management of switchgrass for biomass focuses on harvest timing and frequency for conservation lands, compatibility of production systems with wildlife habitat, and variety selection. Environmental research includes measuring soil carbon sequestration under switchgrass and green house gas emissions from switchgrass production. Research is conducted in collaboration with Penn State University, Colorado State University, USDA-ARS scientists at Lincoln, NE, St. Paul, MN, Madison, WI, Wyndmoor, PA, and Ft. Collins, CO. A critically important part of the program is the on-farm research with producers in Maryland and Pennsylvania. The on-farm research provides opportunities to do research at relevant landscape scales and also serves as a technology transfer mechanism. Recent research accomplishments include a resource assessment of the botanical composition, biomass yield, and biofuels quality of biomass on conservation lands; demonstrating the potential for using switchgrass bioenergy cropping to reduce greenhouse gas emissions from agriculture; and developing seasonal harvest guidelines for switchgrass.

Key words: Bioenergy, carbon sequestration, switchgrass

Switchgrass for Biofuel, Forage, and Mushrooms

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www.ars.usda.gov/main/site_main.htm?modecode=19020000.

Switchgrass (*Panicum virgatum* L.), a native perennial warm-season grass, is used as a forage and conservation plant in the eastern USA. During the last 15 years switchgrass has received much attention as a model energy crop. Attributes of switchgrass desirable for bioenergy cropping include its demonstrated long-term high productivity across many environments, suitability for marginal land, relatively low water and nutrient requirements, and positive environmental benefits. This presentation will preview the tour stops and topics to be discussed during the all day field tour on Thursday October 12. Tour stops will include the Penn State University Russell E. Larson Research Center where USDA-ARS and Penn State collaborative research on harvest management and weed control in switchgrass will be highlighted. Also featured will be a stop at the Penn State Mushroom Test Facility where switchgrass is used as a substrate for mushroom compost. Lastly, the tour will end at the Haller Beef Research Center where we will highlight USDA-ARS research on energy crop rotations, carbon sequestration, and greenhouse gas emissions from switchgrass and annual energy crops.

Key words: Bioenergy, carbon sequestration, field tour

Grass Farming for Local Energy: Opportunities and Strategies for Utilizing Native Grasses to Deliver Clean Energy for Today's Energy Markets

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With the rising fossil fuel prices and the growing awareness and understanding of the effects of global climate change resulting from the use of fossil fuels, there exists more opportunities for agricultural producers to supply biomass derived fuels to local energy markets. Perennial grasses have the potential to be both economically and ecologically sustainable crops for the production of bio-fuels that can directly replace fossil fuels in many applications. Space heating or combined heat and power applications are well suited for entry into the energy market for farmers, due to the fact that the scale of production of these fuels can match the typical farm operation size. In the Northeast, and other areas of the country with high seasonal heating demands, profitable production for local markets can be achieved at relatively small acreages (several hundred to a couple thousand acres). Whereas, larger applications such as ethanol production or co-firing in power generating facilities will require tens of thousands of acres in relatively close proximity to a facility.

In order for a farmer or small group of farmers to be successful in solid fuel production at this scale, strategies must be in place to ensure delivery of a cost competitive, reliable product for use in the appropriate applications. Locally grown native grasses densified into pellets, cubes, or briquettes can fulfill all such requirements if proper growth, harvest, processing, and storage techniques are employed and the producers pay close attention to end user needs throughout the process. Site selection for growth of feedstock is important, taking into consideration soil texture and composition, fertility, and drainage. Species selection is critical in terms of harvest potential, site adaptation, and long term crop sustainability. Utilizing existing agricultural equipment for processing and storage will help to avoid capital investment costs during the start-up phase while producers establish a market base and initial profitability. Investigations should be made for the utilization of existing grass resources in local communities (e.g. lands established using government programs) as potential feedstock once that land is free from contract. Management practices need to be in place to minimize ash\inorganic fraction (particularly Cl, K, and Si) of feedstock and avoid potential contamination by soil or mineral dust during various stages of harvest and transport. Transportation of bulky feedstock must be minimized to reduce pre-processing costs. Densification must be accomplished for a reasonable cost per unit and must produce a final product which is matched to the end user in terms of quality, convenience, and combustibility. Cooperation amongst producers or the actual formation of a formal cooperative organization will reduce risk involved with capital investment, help with process efficiency, and assure a certain level product consistency. This poster will give further illustration of these and other important considerations for the development of the cropping systems that can supply energy for small scale, local utilization of grass biomass for energy.

Key words: Bioenergy, biomass, densification, grass pellets

Using Switchgrass in a Small-Scale Boiler to Supplement Farm Heating Needs

K. W. Staver

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Planting of warm season grasses on Maryland cropland has occurred primarily in response to state and federal incentive programs aimed at reducing nutrient inputs to the Chesapeake Bay. These programs have focused on taking land out of production in areas with potential to retain nutrients lost from up gradient cropland such as riparian buffers and wetlands. A secondary objective of these programs has been to provide wildlife habitat. However, to date there has been little effort to develop production systems that utilize warm season grasses as a harvestable crop. In fact, harvesting is prohibited in riparian buffers installed through the Conservation Reserve Enhancement Program (CREP), the primary program promoting warm season grass plantings in Maryland. However, with recent increases in fossil fuel prices and concerns regarding increasing atmospheric CO_2 concentrations interest has increased in the use of biofuels. This suggests that in the long term, options should be considered that couple water quality incentive programs with biofuel production to achieve both air and water quality benefits as well as less dependence on fossil fuels.

There has long been interest in using switchgrass (*Panicum virgatum* L.) as a biofuel, with the primary focus being on its use as feedstock in ethanol production or in large-scale electricity generating facilities. Long-term studies have demonstrated that switchgrass grows well in Maryland and has minimal nitrogen losses relative to row crops. However, Maryland lacks the cropland area to support large-scale centralized biofuel systems such as those being proposed in the Midwestern USA. A currently available option for utilizing switchgrass as a biofuel in Maryland is as fuel in small-scale on-farm combustion systems, an approach used widely in Europe to utilize cereal straw. To test the feasibility of this approach, a boiler designed to burn cereal straw was installed in 2004 at the UMD Wye Research and Education Center to supplement space heating needs in farm buildings. The system was fueled throughout the 2005-2006 heating system with spring harvested switchgrass. The primary problem encountered was obtaining sufficient air flow early in the combustion cycle due to the lack of cohesiveness of baled switchgrass. Energy capture in the heating system was approximately 50 percent, suggesting that 1 ton of switchgrass would replace the heating value of approximately 70 gallons of heating oil used in a system with an efficiency of 75 percent. Although using switchgrass as a fuel in small-scale systems appears to have potential for providing multiple environmental benefits, its adoption will likely remain limited by the current lack of affordable combustion systems and local technical support. Development of automated feed systems would greatly enhance the potential for utilizing switchgrass as a biofuel in Maryland.

Key words: Biofuels, combustion systems, Maryland, switchgrass

Biomass

Switchgrass (*Panicum virgatum* L.) Use by the Caddo Tribe for House Construction

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Abstract

The Caddo Indian tribe's range was northwest Louisiana, northeast Texas, eastern Oklahoma, western Arkansas, and southwest Missouri. Historical records indicate the use of native switchgrass (*Panicum virgatum* L.) in the construction of houses. Selections are being monitored at Fort Polk, Louisiana and at Haskell University in Lawrence, Kansas to select strains for this cultural use.

Key words: Caddo Tribe, house construction, switchgrass

Background

The Caddo Tribe original home was northwest Louisiana, northeast Texas, eastern Oklahoma, western Arkansas, and southwest Missouri (Glover 1935; Newkumet and Meredith 1988; Swanton 1942). The historical records indicate the construction of grass houses using the native and apparently abundant switchgrass. This range of the Caddo tribe included parts of current day Fort Polk in west Central Louisiana. Haskell University is a Native American University located in Lawrence, Kansas and some students with Caddo roots attend this University. The range of switchgrass includes Louisiana and Kansas and most of the United States (Allen et al 2004; USDA NRCS 2006).

Methods

Fort Polk has an ongoing project with the major objective of locating and propagating native grass species for erosion control and re-vegetation across the base. The native species being screened include big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* Michx. Nash), slender bluestem (*S. tenerum*), eastern gamagrass (*Tripsacum dactyloides* (L.) L.), Indiangrass (*Sorghastrum nutans* L. Nash), and switchgrass. Since 2001, selections of these species were located on Fort Polk or nearby and then propagated and monitored. In 2004, this native grass program was expanded to include the monitoring of switchgrass for house construction. Additional selections of switchgrass from northwest Louisiana, northeast Texas, eastern Oklahoma, western Arkansas, and Kansas were added. All selections are being shared with faculty and interns at Haskell University in Lawrence, Kansas.

The switchgrass characteristics that are important for house construction include: (1) number of stems, (2) diameter of stems, (3) height of plants, and (4) seed production. Both Fort Polk and Haskell University set up a monitoring plan to screen the selections for: (1) more stems, (2) large stems, (3) taller plants, and (4) more seeds. In February 2005, a total

of 42 selections were planted at Fort Polk that included 4 clumps of each selection for a total of 168 clumps. The clumps were measured monthly with the final and reporting measurement taken in October 2005. The stem diameter was not measured in 2005 but after consultation with Phil Cross, the stem diameter was added and will be measured in the future. Additional selections including some from southwest Missouri were added in 2005.

Results

The summarized October 2005 switchgrass measurements for the 42 selections are in Table 1. The raw data were synthesized and mean values and standard deviation calculated for stem number and plant height. The number of clumps is also listed. The data are listed for all selections and then by Louisiana or non-Louisiana (Arkansas, Kansas, Oklahoma, or Texas). The number of stems and plant heights calculations were also done using the viable clumps only. The number of clumps that survived will be evaluated after the 2006 growing season. During the calculations, it seemed that the clumps that were planted from selections that were already grown in pots for one or more years were growing better than those that were transplanted directly from the field. The data were re-calculated after dividing the measurements into those that were grown in pots and those that were transplanted directly into the field. The number of clumps with seed production is listed for all clumps and for the Louisiana or Non-Louisiana clumps and for the pot grown and transplanted clumps. The individual selections were examined for most stems, tallest plants, and most clump seed production (Table 2).

Discussion

The results at the end of the first year indicated a strong correlation between local Louisiana switchgrass and the good characteristics (more stems, taller plants, and more seeds) for house building (Table 1). But on closer examination, these characteristics may have been linked to a better and stronger clump at the beginning of the growing season for most of the Louisiana selections. Most of the Louisiana selections had been obtained from the field and grown under controlled conditions for the past several years while most of the Non-Louisiana selections were transplanted from their original location to the field. The final conclusions await measurements from future years and also from the Kansas plantings at Haskell University.

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Table 1. Summary data for switchgrass selections grown at Fort Polk, Louisiana during 2005

	All Clumps			Viable Clumps (October 2005)		
	Mean	Std. Dev.	No.	Mean	Std. Dev.	No.
	-----------------------------Mean number of stems-----------------------------					
All Selections	1.2	2.92	168	4.1	4.05	51
Non-Louisiana	0.05	0.22	60	1.0	0.00	3
Louisiana	1.9	3.46	108	4.3	4.10	48
Pot Grown	2.6	3.68	92	4.6	4.21	43
Transplanted	0.5	0.89	16	1.6	0.89	5
	---------------------------Mean plant height (in.)----------------------------					
	Mean	Std. Dev.	No.	Mean	Std. Dev.	No.
All Selections	9.9	15.90	168	32.6	9.56	51
Non-Louisiana	1.0	4.19	60	19.0	1.73	3
Louisiana	14.8	17.75	108	33.4	9.20	48
Pot Grown	15.8	18.05	92	33.9	8.94	43
Transplanted	9.1	15.18	16	29.2	11.45	5

	Seed production		
	No. with seeds	No. of clumps	No. of viable clumps
All Selections	33	168	51
Non-Louisiana	0	60	3
Louisiana	33	108	48
Pot Grown	30	92	43
Transplanted	3	16	5

Table 2. Preliminary ranking of selections of switchgrass grown at Fort Polk, Louisiana during 2005

Selection	Mean # Stems	Mean Hgt (in.)	No. with Seeds	Combined
46	3.5	39.2	4	46.8
36	5.8	31.5	3	40.2
33	2.5	34.5	3	40.0
Gooselake 3	8.2	28.2	3	39.5
31	1.8	32.0	3	36.8
34	4.0	24.2	3	31.2
3	8.5	22.5	1	31.0
Gooselake 1	6.2	23.5	0	29.8
29	2.5	26.0	2	28.0
41	2.5	23.0	1	23.0

Influence of Time of Stand Establishment on Biomass Production of Eastern Gamagrass

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Abstract

Recent studies conducted at the Beltsville Agricultural Research Center (BARC) have demonstrated the ability of eastern gamagrass [*Tripsacum dactyloides* (L.) L.] to adapt to acid, compact soils and to produce high quality forage. However, little is known as to yield comparisons between young and old stands. This study was conducted to determine the comparative yield of young (planted in 1999) and old (planted in 1996) stands of 'Pete' eastern gamagrass grown on an acid, compact soil at BARC during the summer of 1999 and 2000 and to assess possible differences in biomass obtained in the spring and summer of 2000. Biomass data were also collected on these plots from 2001 to 2005 to determine whether initial differences in biomass between young and old stands persisted during subsequent years. A comparison of summer yields (August 1999 and August 2000) showed a significant interaction between age and time due to changes in the means for young plants in the two years. A comparison of yields taken during spring and summer 2000 indicated that young stands out-yielded old stands by 50%; however, there was no difference between spring and summer yields within each age group. Initial differences in biomass between young and old stands persisted until termination of the study in 2005. Although published guidelines recommend harvesting eastern gamagrass plants only in the second year, our results indicate that it is feasible to obtain high amounts of biomass within three months of seeding provided that adequate soil moisture is available.

Key words: Acid compact soils, biomass production, eastern gamagrass

Introduction

Recently, there has been renewed interest in the Eastern United States in the use of eastern gamagrass (Horner et al. 1985, Bidlack et al. 1999, Coblentz et al. 1999, Krizek et al. 2003a), switchgrass (*Panicum virgatum* L.) (Anderson et al. 1988, Reid et al. 1992), and other warm-season grasses for forage production, soil improvement, and conservation of water and nutrients (Dickerson et al. 1997, Ritchie et al. 2000, Perrygo et al. 2001). Recent studies conducted at the Beltsville Agricultural Research Center at Beltsville, Maryland have demonstrated the ability of eastern gamagrass to adapt to acid, compact soils (Foy 1997, Foy et al. 1999, Gilker et al. 2002, Krizek et al. 2003b) and to produce high quality forage (Reeves 1987, Ritchie et al. 2006).

Studies conducted at Beltsville, Maryland from 1997 to 2001 on a derelict soil site having a 25% slope on the North Farm at the Beltsville Agricultural Research Center (BARC) indicated that eastern gamagrass plants sown in 1996 produced relatively high average yields of biomass (1.7 to 2.7 t ac^{-1}) on an acid, compact soil (average pH 4.8) despite severe droughts during three of these years (1997 to 1999) (Krizek et al. 2003b). Foy et al. (1999)

reported that additions of lime to a site at the bottom of the slope (pH 5.1, unlimed and pH 5.8, limed) (designated Site 1) had no significant effect on forage yields over a two-year period (1997-1998). Forage composition and quality also appeared to be largely unaffected by low pH and soil compaction (Ritchie et al., 2006). However, little is known as to yield comparisons between young and old stands of eastern gamagrass. The objective of this study was to determine the comparative yield of young and old stands of 'Pete' eastern gamagrass grown on an acid, compact soil on the North Farm at BARC during the summer of 1999 and 2000 and to assess possible differences in biomass obtained in the spring and summer of 2000. Biomass data were also collected from 2001 to 2005 to determine whether initial differences in biomass observed between young and old stands persisted during subsequent years.

Materials and Methods

Site: The location used for the study was at the bottom of a 750 ft hillslope (22% slope) on a derelict site on the North Farm at BARC. Prior to sowing seed of eastern gamagrass, this hillslope had been covered with mixed grasses dominated by tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire] for over 30 years (Foy et al. 1999). This bottom site, designated as Site 1 (Krizek et al. 2003b, Ritchie et al. 2006) consisted of nine 12x12 ft replicated randomized plots and has been described in detail previously (Foy et al. 1999, Krizek et al. 2003b, Ritchie et al. 2006. This site was chisel plowed to a depth of 12 inches and then roto-plowed to a depth of 6 inches prior to hand sowing eastern gamagrass seed.

Soil and Nutrient Conditions: The experimental research site consisted of an acidic, Al-toxic, no-till soil characterized as a complex of Matawan-Hammonton loam. Half of the plots in Site 1 were limed (pH 5.8) and half of the plots were unlimed (pH 5.1) as described by Foy et al. (1999). Lime was applied in the fall of 1994 and again in May 1995, each time at a rate of 1 ton ac^{-1}. This soil complex contained less than 15% gravel and ranged in texture between clay loam and loamy sand with low soil pH and generally poor soil conditions (Foy et al. 1999; Krizek et al. 2003b, Ritchie et al. 2006). Surface applications of 19-19-19 fertilizer were added at the following rates in 1996, 1997, 1998, 1999, and 2000, respectively: 450, 250, 250, 150 and 260 lbs ac^{-1} on the basis of recommendations of Maryland Cooperative Extension. Mineral analyses were conducted at the University of Maryland and are described by Krizek et al. 2003b. To ensure successful stand establishment, the plots of eastern gamagrass were irrigated several times during the summer of 1999 by means of a sprinkler system. Both the new and old stands were irrigated.

Plant Material

Plant material consisted of two stands of eastern gamagrass, cv. Pete grown from seed on an acid, compact soil at the Beltsville Agricultural Research Center: an old stand planted in May 1996 and a young stand planted in May 1999. The young stand was established on plots that were formerly planted in soybean, barley, wheat, and snap bean, during 1994 to 1996 (Foy et al. 1999). Seed consisted of Germtec™ -treated eastern gamagrass seed that was obtained from Gamagrass Seed Co. (Falls City, NE). Seed were hand sown in 18 inch rows, about 1.5 inches apart.

Biomass Production

To compare the performance of young vs old plants, plants were harvested manually for biomass on August 13, 1999, June 8, 2000, and August 30, 2000. Biomass data were also collected during the subsequent five years (2001 to 2005) to determine persistence effects. The plants were cut back to a height of 4 inches at time of harvest and three foot strips were taken for biomass determination. Samples were dried in a forced-draft oven at 140°F and weighed after at least 48 h. Yields were calculated on a t ac^{-1} basis.

Statistical Analysis

Yield data obtained during the summer of 1999 and 2000 were analyzed as a two-factor general linear model using PROC MIXED (SAS Institute 2004) with AGE and TIME as the factors The variability between limed and unlimed plots was accounted for and modeled with the compound symmetric correlation structure. The assumptions of the general linear model were tested. The AGE means were compared at the 0.05 significance level. To correct variance heterogeneity, the treatments were grouped into similar variance groups for the analysis. The means were compared using pair-wise comparisons with Sídak adjusted p-values so that the experiment-wise error for the comparison category was 0.05. To examine the persistence effect of treatment, the biomass yield data were analyzed as a repeated measures two-factor general linear model for the factors AGE and YEAR (the repeated factor) using PROC MIXED (SAS Institute 2004). The data were standardized so that various variance-covariance structures could be used to fit the repeated effect. The heterogeneous autoregressive(1) structure was found to have the best fit. Assumptions of the linear model were tested. As AGE and YEAR were statistically significant, mean comparisons were done with Sidak adjusted p-values so that the experiment-wise error was 0.05. The means in Table 6 are in the original units.

Results and Discussion

Appearance of Plants

Within three months of planting the seed in 1999, the plants were nearly 20 inches high. By May 2000, the replicated stands of young plants were as tall as the old stands planted in 1996 and appeared more robust than the old stands. There were no obvious differences in appearance between limed and unlimed plots.

Comparison of Yield During August of 1999 and 2000

The ANOVA (Table 1) indicates that there was a significant interaction between AGE and TIME; this was shown to be due to the change in the means for young plants in 1999 and 2000 (Table 2). The mean biomass of young plants harvested in August 1999 was lower than the mean biomass of old plants; however, in 2000, young plants had higher yields than old plants (Table 2).

Comparison of Yield during June and August 2000

Based on the ANOVA, only age of the eastern gamagrass stands mattered (Table 3). A comparison of yields taken during spring and summer 2000 (Table 4) indicated that young stands out yielded old stands by 50% (3.2 vs. 2.2 t ac^{-1}), however, there was no difference between spring and summer yields within each age group.

Persistence of Treatment Effects to 2005

Table 5 shows that there were significant Age and YEAR effects. Means and mean comparisons are shown in Table 6. These results indicate that initial differences in biomass observed in 2000 between young and old stands persisted during the next five years of the study 2001 to 2005). From 2000 to 2001, there was a significant reduction in biomass which could be attributed to infestation of the eastern gamagrass plants by the southern cornstalk borer (*Diatraea crambidoides* (Grote), Crambidae: Crambinae, LEPIDOPTERA (Krizek et al. 2004). This damage was particularly prevalent on the young and old plants in the experimental plots in Site 1 (at the bottom of the slope). It is interesting to note, from a plot of yield data from 2002 to 2005, that the old plants failed to show much recovery while the young plants tended to resume growth (data not shown).

Efficacy of Growing Eastern Gamagrass as a Forage Crop

Related studies conducted in our laboratory (Ritchie et al. 2006) and in other locations (Bidlack et al. 1999, Coblentz et al. 1999) confirm its suitability as a high quality forage crop because of its high protein content, relatively low lignin content, high palatability, and high digestibility.

Conclusions

Eastern gamagrass plants are ideally suited for marginal sites because of their tolerance to acid, Al-toxic, compact soils that are frequently subjected to waterlogging. Data on biomass production of plants grown on limed and unlimed sites at Beltsville indicate that this species would be valuable in a sustainable agricultural system because of its excellent growth during hot, dry summers when cool-season grasses are dormant. The present study demonstrated that under irrigated conditions, it is feasible to obtain high amounts of biomass even within three months of seeding. Our findings indicate that young stands of eastern gamagrass were capable of out producing older stands nearly two-fold and that initial differences in yield persisted for several years.

Acknowledgments

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Table 1. Analysis of variance of eastern gamagrass yields during August 1999 and 2000

Source	Df	F-value	p-value
Age	1	1.90	0.1928
Time	1	32.36	0.0001
Age x Time	1	40.14	0.0001

Table 2. Mean comparisons (t ac^{-1}) of eastern gamagrass yields during August 1999 and 2000

	Time		Age Mean
Age	1999	2000	
Old	2.32a[1]x[2]	2.18bx	2.25
Young	0.57by	3.29ax	1.93
Time Mean	1.45	2.73	

[1] Age means within Time (columns) with different letters (a, b) are different at the significance level 0.05.
[2] Time means within Age (rows) with different letters (x, y) are different at the significance level 0.05.

Table 3. Analysis of variance of eastern gamagrass yields during June and August 2000

Source	Df	F-value	p-value
Age	1	12.50	0.0033
Time	1	0.04	0.8508
Age × Time	1	0.01	0.9198

Table 4. Mean comparisons (t ac^{-1}) of eastern eamagrass yields during June and August 2000

	Time		Age Mean
Age	Spring	Summer	
Old	2.16	2.18	2.17b[1]
Young	3.23	3.29	3.26a
Time Mean	2.69	2.73	

[1] Age means with different letters are different at the 0.05 significance level.

Table 5. Analysis of variance of eastern gamagrass yields during 2001 to 2005 demonstrating dersistence of treatment effects

Source	Df	F-value	p-value
Age	1	6.18	.0283
Year	4	58.43	<.0001
Age ×Year	4	2.26	.0930

Table 6. Means and mean comparisons (t ac^{-1}) of eastern gamagrass yields during 2001 to 2005 demonstrating persistence of treatment effects

Year	Mean	Age	Mean
2001	5.91a[1]	Young	4.58a[2]
2002	2.96c	Old	3.52b
2003	3.36bc		
2004	4.20b		
2005	3.81bc		

[1] Year means with different letters are different at the 0.05 significance level.
[2] Age means with different letters are different at the 0.05 significance level.

Effects of Manure Application and Harvest Timing on Switchgrass and Big Bluestem Biomass and Seed Production across Landscape Positions

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Abstract

A principle attribute of perennial grasses for biomass is the potential for high yields on marginal land. The objective of this study was to compare biomass and seed production of big bluestem (*Andropogon gerardii* Vitman) and switchgrass (*Panicum virgatum* L.) as affected by harvest timing and manure application on backslope (not suitable for corn production) and footslope (suitable for corn production) positions. Grasses were harvested at anthesis (summer), after a killing frost (fall), or allowed to over-winter in the field and harvested the following spring (spring) from 2003 to 2005. Seed was harvested at maturity in 2003 and 2004. Two rates of beef cattle (*Bos taurus*) manure (target rates of 0 and 130 lb total-N ac^{-1}) were surface applied during spring 2003 and 2004. Maximum annual biomass yield ranged from 1.17 to 1.86 and 1.64 to 2.51 tons ac^{-1} for big bluestem and switchgrass, respectively. Biomass yields were not different between fall and over-wintered, spring harvest treatments. With normal precipitation, biomass of big bluestem and switchgrass on backslopes was 86% and 96% of biomass on footslopes, respectively. Manure application increased production approximately 30% during the second year (2004) on both landscape positions but had no effect the first year (2003). Averaged across landscape position, switchgrass and big bluestem seed yields were 48 and 19 lb ac^{-1}, respectively, but seed production was not consistent across years. These results demonstrate the potential to utilize switchgrass and big bluestem as dedicated bioenergy crops on marginal land. Furthermore, it may be possible to allow the crop to over-winter in the field without losing significant biomass.

Key words: Biofuels, harvest timing, nitrogen response, soil fertility

Introduction

Perennial warm-season grasses, such as switchgrass and big bluestem, are native to the tallgrass prairie and important in forage production, conservation, and wildlife habitat (Moser et al. 2004). Another important aspect of switchgrass is its potential use for bioenergy production (Sanderson et al. 2004), particularly on marginal lands not suitable for row crop production (Vogel 1996).

Fertilization and harvest management practices are important aspects of sustainable biomass production of perennial grasses. In general, a single harvest late in the fall or during the winter has been recommended for maximum yield and quality of perennial feedstocks. Although the N-use efficiency of warm-season grasses is very good, they may respond to N fertilizer, particularly on soils low in this nutrient. Because of its nutrient and organic matter content, cattle manure is a valuable resource for grass production and soil conservation. Research has demonstrated that cattle manure is a good source of N for perennial grasses (Cherney et al. 2002; Sanderson et al. 2001). As an added benefit, perennial grasses provide

permanent ground cover and reduce problems with soil erosion and runoff in fields to which manure is applied (Sharpley and Harverson 1995).

A shift toward biomass feedstock production of perennial grasses on marginal land would enhance the region's soil organic carbon, soil quality, water quality, wildlife habitat, and help revitalize rural economies. However, little information is available regarding production and management strategies for biomass production of warm-season grasses on marginal lands in the northern Great Plains. The objective of this study was to compare biomass and seed production of switchgrass and big bluestem as affected by harvest timing and manure application across a topographic sequence ranging from suitable to unsuitable for corn production in the northern Great Plains.

Materials and Methods

This experiment was conducted from 2003 to spring 2005 at the USDA-ARS Research Farm (96°45'W; 44°19'N) near Brookings, SD. Dominant soils at the site are a Sioux gravelly loam (sandy-skeletal, mixed Udorthentic Haploborolls) on summit and upper backslope positions and a Svea loam (fine-loamy, mixed Pachic Udic Haploborolls) on lower backslope and footslope positions. The Sioux series is classified as a land capability class 6/7, rated not suitable for corn production, and the Svea series is classified as land capability class 1, rated suitable for corn production. Big bluestem and switchgrass were established across a topographical gradient in 2000. Each species and four fallow strips were randomly assigned within each of four blocks and planted 10 ft wide and 400 ft long. The site was not harvested or fertilized until treatments were imposed in 2003.

The experimental design was a split-split-plot arrangement of a randomized complete block. Species (n = 2) were treated as whole plots, harvest timing (n = 3) as sub-plots, and manure treatment (n = 2) as sub-sub-plots (10 ft by 10 ft). Treatments were replicated four times on backslope and footslope positions. Three harvest timing treatments were imposed including; i) harvesting for forage at anthesis (summer), ii) biomass/seed production with seed harvest at maturity and fall biomass harvest to a stubble height of 4-6 in (fall), and iii) biomass/seed production with seed harvest at maturity and biomass harvest the following spring to a stubble height of 1-2 in (following spring). One-half of each sub-sub-plot received approximately 130 lb total-N ac^{-1} as manure from a beef cattle feedlot each year. The other half of each sub-sub-plot served as a 0-N control and received no manure. Preweighed manure was hand-broadcast on the surface of each plot 11 June 2003 and 3 May 2004.

Seed was harvested from entire sub-sub-plots before harvesting biomass in the fall or following spring. Seed of big bluestem and switchgrass was harvested 2 September and 30 September 2003, respectively. Big bluestem and switchgrass seed was not harvested in 2004 because of poor environmental conditions for seed development. Biomass was harvested from entire sub-sub-plots with a sickle-bar mower on the dates shown in Table 1. Dry matter yield was determined for each sub-sub-plot by taking a grab sample (about 2 lb) from the harvested biomass, drying it at 135°F for 72 h in a forced-air oven, then reweighing for DM determination.

Total biomass production was analyzed separately by harvest year and topographic location using a split-split-plot design with species as whole plots, harvest timing as sub-plots, and manure treatment as sub-sub-plots with four replications. Harvest timing was not included for seed yield analysis; therefore, species was treated as whole plots and manure

treatment as sub-plots with eight replications in 2003. Least significance differences (LSD) were used to separate means when *F*-tests were statistically significant.

Results and Discussion

Biomass Production – Species Effect

Biomass yields differed significantly between species on both landscape positions and between years, with the exception of the backslope position in 2004 (Table 2). The lack of significance on the backslope was associated with increased yield variability across the stand. Biomass production of switchgrass and big bluestem was 60% and 73% higher, respectively, in 2004 than 2003 because of higher April-May precipitation in 2004. Lee and Boe (2005) reported a strong linear relationship between April-May precipitation and maximum switchgrass production in central South Dakota.

Maximum annual biomass yield was obtained from footslope positions and ranged from 1.17 to 1.86 and 1.64 to 2.51 ton ac^{-1} for big bluestem and switchgrass, respectively. In 2003, biomass yield on backslopes was 71% and 87% of that on footslopes for big bluestem and switchgrass, respectively. However, with increased April-May precipitation in 2004, biomass production on backslopes increased to 86% and 96% of that on footslopes for big bluestem and switchgrass, respectively. Our results indicate that these warm-season grasses may produce considerable biomass with appropriate precipitation during early spring even on soils which are not suitable for corn production.

Biomass Production – Harvest Timing Effect

Biomass yields were not different among harvest treatments on either topographic position (Table 3). Although yields declined approximately 10%, production of over-wintered switchgrass harvested near ground level the following spring was not significantly different from biomass harvested at a 4-6 in. stubble height the previous fall. Lee and Boe (2005) found that decreased biomass due to weathering during the winter could be compensated for by harvesting near ground level to include the basal portion of the plant. We have observed that over-wintering would likely work better with switchgrass than big bluestem as switchgrass remains more erect and big bluestem lodges during the winter months.

Biomass Production – Manure Application Effect

Manure application significantly affected biomass production at both topographic positions in 2004 but not in 2003 (Table 4). In 2004, biomass increased approximately 28% and 31% with manure application on backslope and footslope positions, respectively. Even though manure was applied during active vegetative growth in 2003, surface broadcasting of manure during a hot/dry season may provide limited nutrients for growth. In addition, limited mineralization in the first year of application (2003) may have resulted in inadequate available N for plant growth. Sanderson and Jones (1997) found that manure application did not significantly increase bermudagrass (*Cynodon dactylon* L. Pers.) forage yield in the first year of application because of slow mineralization of manure-N.

Seed Yields

Seed yields were significantly different between grass species in 2003 (Table 5). Maximum seed production for big bluestem and switchgrass was obtained on footslopes. Big

bluestem and switchgrass seed production on backslopes was 69% and 80% of that on footslopes, respectively. Seed yields tended to increase with manure application, but differences were not statistically significant.

Averaged across all treatments in 2003, switchgrass and big bluestem seed yields were 48 and 19 lb ac^{-1}, respectively. In the same year, Boe (personal communication) reported switchgrass seed yield of 71 lb ac^{-1} in northeastern South Dakota. In Pennsylvania, Sanderson et al. (2004) reported switchgrass and big bluestem seed yields of 27 to 250 lb ac^{-1} and 2 to 30 lb ac^{-1}, respectively. Boe et al. (2004) noted that big bluestem averages about 50 lb seed ac^{-1} on dryland in the northern Great Plains.

Summary and Conclusions

Big bluestem and switchgrass have potential for bioenergy feedstock production on marginal land in eastern South Dakota. With normal precipitation, these perennial grass species produced comparable biomass on land designated unsuitable or suitable for corn production. Big bluestem and switchgrass produced maximum biomass when harvested in the fall, but yields were similar for fall-harvested and over-wintered, spring-harvested biomass. Manure could be used as an alternate source of N for biomass and seed production of perennial grasses, but we noted no effect of manure until the second year of application. Although seed production of these grasses was not consistent across years, this may provide another potential source of income for producers desiring to grow a perennial bioenergy crop.

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Table 1. Harvest dates for big bluestem and switchgrass during 2003, 2004, and 2005 at the USDA-ARS Research Farm near Brookings, SD

	Harvest timing		
Species	Summer	Fall	Following Spring
Big bluestem	18 July 2003	2 Sep. 2003	31 March 2004
Switchgrass	29 July 2003	30 Sep. 2003	31 March 2004
Big bluestem	20 July 2004	4 Nov. 2004	14 April 2005
Switchgrass	2 Aug. 2004	4 Nov. 2004	14 April 2005

Table 2. Biomass production of big bluestem and switchgrass on two landscape positions during 2003 to 2005 at the USDA-ARS Research Farm in eastern South Dakota. Values are averaged across harvest timing and manure application treatments.

	2003-04		2004-05	
	Backslope	Footslope	Backslope	Footslope
	ton DM ac^{-1}			
Switchgrass	1.43	1.64	2.40	2.51
Big bluestem	0.83	1.17	1.60	1.86
$LSD_{0.05}$	0.45	0.38	NS	0.57

Table 3. Harvest timing effect on biomass production of switchgrass and big bluestem on two landscape positions from 2003 to 2005 at the USDA-ARS Research Farm in eastern South Dakota. Values are averaged across species and manure application treatments.

	2003-04		2004-05	
	Backslope	Footslope	Backslope	Footslope
	ton DM ac^{-1}			
Summer	1.11	1.33	1.78	1.93
Fall	1.23	1.49	2.09	2.40
Following spring	1.06	1.40	2.12	2.22
$LSD_{0.05}$	NS	NS	NS	NS

Table 4. Manure application effect on biomass production of switchgrass and big bluestem on two landscape positions from 2003 to 2005 at the USDA-ARS Research Farm in eastern South Dakota. Values are averaged across species and harvest timing treatments.

	2003-04		2004-05	
Manure Trt.	Backslope	Footslope	Backslope	Footslope
	ton ac^{-1}			
No manure	1.16	1.40	1.75	1.89
Manure applied	1.11	1.42	2.24	2.47
$LSD_{0.05}$	NS	NS	0.20	0.36

Table 5. Seed yield of big bluestem and switchgrass on two landscape positions during 2003 at the USDA-ARS Research Farm in eastern South Dakota. Values are averaged across harvest timing and manure application treatments.

Species	2003 Backslope	2003 Footslope
	---------------------- lb ac^{-1}	----------------------
Switchgrass	43	53
Big bluestem	16	23
$LSD_{0.05}$	19	19

A Nine-Year Study of Biomass Production by Eastern Gamagrass

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Abstract

With increasing emphasis on sustainable agriculture, there is renewed interest in the use of native plants as alternative sources for forage, fuel, and soil improvement. Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a native, warm-season, perennial grass that is found in the eastern United States and is used for forage, fuel, and soil improvement. The objective of this study was to measure biomass production of eastern gamagrass grown on a degraded, acid soil at the Beltsville Agricultural Research Center, Beltsville, MD. Eastern gamagrass was planted in 1996 and forage samples were harvested and biomass determined at time of heading from 1997 through 2005 from plants grown on the degraded hill slope with increasing soil acidity and decreasing surface soil depth from the bottom to top of the hill slope. Slope position and year of harvest had the greatest effect on biomass production. In general, eastern gamagrass biomass was related to soil conditions and environmental stress (rainfall). This 9-year study would indicate that it is probably the timing of the rainfall that is more important than the total annual rainfall.

Key words: Biomass, degraded soils, eastern gamagrass, warm-season grass

Introduction

With increasing emphasis on sustainable agriculture, there is increased interest in using native plants as alternative crops for forage, fuel, and soil improvement. Eastern gamagrass is a native, warm-season, perennial bunch grass that is found from the east coast to western Kansas and from Florida to upper New York in the United States (Dickerson et al. 1997) and widely used for forage (Horner et al. 1985; Coblentz et al. 1999). It can grow in acid, Al-toxic soils that are severely restricting to most crop plants (Foy 1997; Foy et al. 1999). Eastern gamagrass produces high yields of forage (Krizek et al. 2003) with reported protein content and forage palatability comparable to that of alfalfa forage (Horner et al. 1985; Bidlack et al. 1999; Ritchie et al. 2006). Although reports have shown eastern gamagrass to be a high producing forage compared to other forage plants, relatively little research has been done concerning the effects of soil conditions on forage production. The objective of our research was to investigate long-term production of eastern gamagrass forage grown on a degraded, acid soil at the Beltsville Agricultural Research Center, Beltsville, MD.

Methods and Materials

Study Site: Eastern gamagrass, cultivar Pete, was planted in 1996 on six sites located along a 800 ft. hillslope having a 22% slope on a degraded phase of Matawan-Hammonton loam

soil complex. This soil complex contained less than 15% gravel and ranged in texture between clay loam and loamy sand with low soil pH and generally poor soil quality (Foy et al. 1999; Krizek 2003). The A horizons became thinner from the bottom to the top of the hillslope (Sites 1 to 6) indicating greater erosion and soil degradation at the upper slope sites (USDA 1995; Ritchie 2006). Soil pH (1:1 soil-water suspension) in the surface layer (Foy et al. 1999) varied from 5.1 at the bottom of the slope (Site 1) to 4.3 at the top of the hillslope (Site 6). Bulk density measurements at depths of 0-15, 15-30, and 30-45 cm ranged from 0.98 to 1.24 g cm^{-3} at the bottom of the hillslope to 1.16 to 1.64 g cm^{-3} at the top of the hillslope (Krizek et al. 2003). Prior to planting eastern gamagrass, the hillslope had mixed grasses dominated by tall fescue [Lolium arundinaceum (Schreb.) SJ. Darbyshire] that had not been plowed for more than 30 years.

Site 1, located at the bottom of the hillslope, consisted of nine 12x12 ft. plots described in detail by Foy et al. (1999). Only 4 of the 9 plots were used in this study and the biomass values for these four plots were averaged to determine the biomass for Site 1. Sites 2 to 6 were located up the hillslope from Site 1 with Site 6 being at the top of the hillslope. Site 1 was chisel plowed to a depth of 12 in. and then roto-plowed to a depth of 6 in. prior to hand planting seed. Sites 2 to 6 were no-till planted with a corn planter after application of RoundUp™ to kill the sod. Sites 2 to 6 ranged in size from 1000 to 2000 ft^2 with 12 to 18 rows each. Eastern gamagrass at Site 1 was planted in 18-in. rows while Sites 2 to 6 were planted in 30-in. rows. All sites were fertilized in the spring with 19-19-19 fertilizer at rates of 450, 250, 250, and 150 lbs ac^{-1} in 1996, 1997, 1998, and 1999, respectively and at 250 lbs ac^{-1} in the spring of 2000, 2001, 2002, and 2003. No fertilizer has been added since 2003.

<u>Rainfall;</u> Total rainfall varied from 30.6 to 51.3 in. over the 9-year period (Table 1). These values represent a deficit of 11.4 in. and a surplus of 9.3 in. when compared to the average yearly rainfall of 42.0 in. for the period between 1871 and 2000 at the Baltimore-Washington International Airport located approximately 15 miles northeast of the study site. Rainfall of 40.2 and 51.3 in. occurred in 1999 and 2003, respectively but over half of that occurred (23.1 and 27.1 in.) occurred from late July to December in both years after eastern gamagrass had finished its maximum growth for the season.

<u>Sampling:</u> Biomass data were collected over a nine-year period (1997 to 2005) at time of heading from each of the six sites. Samples for biomass measurements were collected using 3-ft. strips along rows for each site. At least two locations were collected at each site. Samples were dried in a forced-draft oven at 140° F for 72 hours and weighed to determine biomass.

Statistical Analysis

Statistical analyses were made using Statistix (Analytical Software 2003) to test for differences in biomass by year, site, and annual rainfall using one-way ANOVA and the Least Significant Difference (LSD) tests.

Results and Discussion

Annual eastern gamagrass biomass production ranged from 0.6 to 3.5 tons ac^{-1} for the six sites over the nine-year period (Table 1 and 2). In general biomass production decreased from the bottom (Site 1) of the slope toward the top of the slope. Site 1 had the highest

average production for the 9-year period (2.92±0.68 tons ac^{-1}) and it was significantly ($p>0.05$) greater than the average production at the other 5 sites. Site 1 had the best soil quality as determined by a NRCS soil survey (USDA 1999) and it had been tilled before planting while the other sites were no-till planted into killed sod. There was a significant difference ($p>0.05$) between the production on tilled (Site 1) and no-till sites. Differences between Site 1 and the other sites were most evident from 2000 to 2005 (Fig. 1) when production at Site 1 was about twice that at the other sites. Site 3 had the next highest production and was located on a bench with a deep A-horizon (USDA 1995). Sites 2, 4, 5, and 6 were on generally poorer quality soil sites (Table 1) as determined by USDA NRCS (1995). The depth of the A-horizon decreased from the bottom to the top of the slope indicating greater surface soil loss and poorer soil quality. While no specific measured soil property (pH, bulk density, depth of A-horizon) was significantly related to eastern gamagrass biomass production, it is assumed that at least part of the differences in production among the sites was due the to reduced soil quality from the bottom to the top of the slope (from Site 1 to Site 6).

From 1996 to 2003 all sites were fertilized at a rate of approximately 250 lbs ac^{-1} of 19-19-19 fertilizer. Although no fertilizer has been added since the 2003 growing seasons, eastern gamagrass production has not declined. It will be interesting to determine what changes may occur in the future without fertilizer.

There were significant differences in annual eastern gamagrass production among years (Fig. 1, Table 2) with the year 2000 having a significantly higher ($p>0.05$) production (2.89±0.68 t ac^{-1}) than other years. Year 1999 had the lowest production (0.98±0.44 t ac^{-1}). Annual rainfall was variable over the period (Table 1); however, annual rainfall or any 12 consecutive months (i.e., Feb to Jan, Mar to Feb, etc.) of total rainfall were not significantly correlated with eastern gamagrass production. The best correlation was between April rainfall and eastern gamagrass production with an r^2 value of only 0.13. It should be noted that the two years (1999 and 2003) with over 40 in. of rainfall had the lowest production of eastern gamagrass. During these two years over 50% of the annual rainfall for the year came between late July and December after the eastern gamagrass would have completed maximum growth. The spring of 1999 was especially dry with many visible signs of stress in the eastern gamagrass (Krizek et al. 2003). This 9-year study would indicate that it is the timing of the rainfall that is more important than the total annual rainfall. Our analysis of monthly rainfall patterns has not allowed us to determine what that pattern may be. While there was relatively low biomass production in 1999 due to deficit rainfall during the spring period, in general over the 9-year period, there has been relatively uniform biomass production even with the elimination of fertilizer application the last two years of the study period.

Although there was a significant reduction in eastern gamagrass production between 2000 and 2001, annual rainfall was not appreciably lower (33.5 in.) in 2001 than in 2000 (36.4 in.). In 2001, random patches of eastern gamagrass on several sites showed dieback within 2 weeks after harvesting the plants on June 18. Upon inspection, larvae were found emerging from the crown tissue. Microscopic examination of the larvae revealed the presence of both noctuid and pyraloid larvae. Although adult moths were not observed, the pyraloid larvae were identified as the southern cornstalk borer [*Diatraea crambidoides* (Grote), Crambidae: Crambinae, LEPIDOPTERA]. It may be that the additional stress of the

cornstalk borer (Krizek et al. 2004) contributed to the reduction of eastern gamagrass production since the rainfall difference was not great.

Conclusion

Eastern gamagrass has continued to produce relative high biomass during a nine-year period on a degraded hill slope with increasing soil acidity and decreasing surface soil depth (A horizon) from the bottom to top of the hill slope. No trend toward reduced biomass production was noted over the nine-year period even with the elimination of fertilizer application the last two years of the study period. Biomass production was related to slope position and soil quality but rainfall distribution rather than total rainfall appeared to be the major factor influencing the yearly production. This study demonstrated that eastern gamagrass produced good forage biomass under marginal soil and adverse environmental conditions. As a warm-season forage, eastern gamagrass can provide good forage in warm summer months when cool-season forage production is limited and potentially improve soil conditions on acid degraded soils.

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Table 1. Total annual biomass production by eastern gamagrass [*Tripsacum dactyloides* (L.) L.] grown at six hill slope sites with soil characteristics and annual rainfall.

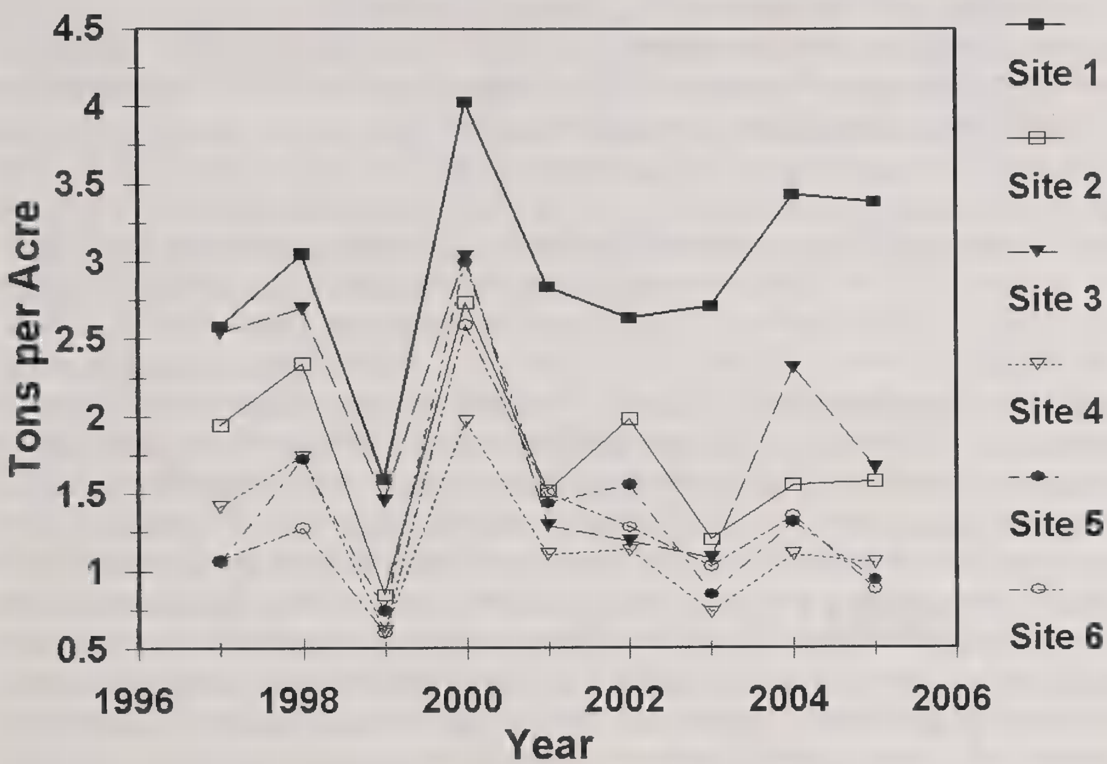
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	
PH	5.60	5.00	4.40	4.25	4.20	4.39	
Bulk Density†	1.23	1.30	1.28	1.32	1.26	1.23	
			Biomass yield (tons ac^{-1})				Rainfall
Year							in.
1997	2.26	1.95	2.54	1.42	1.06	1.07	32.8
1998	2.33	2.34	1.96	1.74	1.73	1.28	35.0
1999	1.40	0.85	1.46	0.61	0.74	0.61	40.2
2000	3.50	2.74	3.17	1.97	3.00	2.59	36.5
2001	2.86	1.52	1.18	1.11	1.44	1.51	33.5
2002	2.85	1.99	1.19	1.14	1.56	1.28	30.7
2003	2.62	1.20	1.09	0.73	0.85	1.03	51.4
2004	3.22	1.56	2.32	1.11	1.32	1.36	37.5
2005	3.20	1.58	1.67	1.05	0.94	0.88	38.2
Mean	2.92±0.68	1.75±0.58	1.92±0.73	1.21±0.44	1.40±0.69	1.29±0.56	

† 0-4 in. soil layer. g cm^{-3}

Table 2. Summary statistics of analyses of variance and means and standard deviation by site and year. Means and standard deviations with different letters in the same column are significantly different at p=0.05 by the LSD test.

F value Sites	F statistics 9.42 p>0.001 tons ac^{-1}	F value Year	F statistics 3.55 p=0.003 tons ac^{-1}
Site 1	2.92±0.68a	1997	1.77±0.69bcd
Site 2	1.75±0.58bc	1998	2.14±0.67ab
Site 3	1.92±0.73b	1999	0.98±0.44d
Site 4	1.21±0.44c	2000	2.89±0.68a
Site 5	1.40±0.69bc	2001	1.62±0.62cf
Site 6	1.29±0.56c	2002	1.63±0.58bcd
		2003	1.27±0.73bcd
		2004	1.85±0.88bc
		2005	1.59±0.94bcd

Figure 1. Total annual biomass production by eastern gamagrass [*Tripsacum dactyloides* (L.) L.] grown at six sites on a hillslope on an acid degraded phase of Matawan-Hammonton loam soil complex at the ARS Beltsville Agricultural Research Center, Beltsville, MD.



Patterns of Growth of Eastern Gamagrass Grown in Sunlit Growth Chambers

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Abstract

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] was grown in six Soil-Plant-Atmosphere-Research (SPAR) sunlit controlled-environment chambers at two levels of carbon dioxide (370 and 740 μmol mol^{-1}) and three temperature regimes (68/57, 82/71, and 95/84°F day/night) for 21 weeks (16 May to 10 October). Leaves (shoots > 4 in. tall) for individual plants were harvested at 8, 16, and 21 weeks. Roots and crowns (shoots 0 to 4 in. tall) were harvested at 21 weeks. Significant differences in leaf growth were found among temperature treatments but no differences were found between $C0_2$ treatments. Individual eastern gamagrass plants grown in SPAR chambers showed growth patterns that were related to their position in the chamber with plants on the north side of the chamber having greater biomass. The patterns of growth in these chambers were similar to the patterns for photosynthetically active radiation (PAR) measurements made in these chambers when plants were not present (Kim et al. 2004). While SPAR chambers are excellent growth facilities for studying physiological and morphological responses, researchers should recognize that there may be positional effects within such chambers.

Key words: Eastern gamagrass, warm-season grass, outdoor growth chambers, temperature effects

Introduction

SPAR (Soil-Plant-Atmosphere-Research) outdoor growth chambers are designed to use natural sunlight to grow plants under controlled conditions (Phene et al. 1978). These controlled environmental chambers are used widely to study physiological and morphological responses of plants to various environmental factors (i.e., temperature, carbon dioxide, ozone), to understand plant growth and development under different environmental conditions, and to develop algorithms for plant simulation models (Liu et al. 2000; Reddy et al. 2001).

Eastern gamagrass plants were grown in six SPAR chambers at Beltsville, Maryland (Krizek et al. 2003; Ritchie et al. 2004). Eastern gamagrass is a warm-season, perennial grass native to North America. It grows under a wide range of environments including drought, flooding, and acid soils (Clark et al. 1998) and, when grown as buffers or filter strips, can reduce runoff of eroded particles and nutrients into riparian zones and streams (Ritchie 2000). It is a palatable and digestible grass with high protein content (Bidlack et al. 1999; Ritchie et al. 2006) thus providing good forage for livestock.

Increases in atmospheric carbon dioxide (CO_2) concentration and projected changes in global climate have gained worldwide attention. Information is needed on how projected

increases in CO_2 and the associated projected increases in atmospheric temperature will affect production of plant species (Reddy et al. 1994; Kimball et al. 2002). Eastern gamagrass has been reported to have one of the highest leaf photosynthetic rates of any C_4 species (Coyne and Bradford 1985). To understand the response of eastern gamagrass to changes in temperature and carbon dioxide, eastern gamagrass was grown in six SPAR chambers at two levels of CO_2 and three temperature regimes. Analyses of data collected from these chambers revealed some significant differences in biomass production related to temperature but not elevated CO_2 (Krizek et al. 2003; Ritchie et al. 2004). During harvest, appreciable differences were noted in the biomass obtained between individual plants within chambers. A recent study conducted by Kim et al. (2004) found a positional effect on the distribution of photosynthetically active radiation (PAR) in these same SPAR chambers. The purpose of this paper was to analyze the variability in biomass production of individual eastern gamagrass plants in the SPAR chambers.

Materials and Methods

Eastern gamagrass was grown in six naturally sunlit SPAR plant growth chambers (Reddy et al. 2001; Kim et al. 2004) at Beltsville, Maryland. Each SPAR chamber consists of a 0.5 in thick clear acrylic (Plexiglas G) chamber (7.5 ft high x 6.9 ft long x 4.2 ft wide) on a rooting bin (3.0 ft high x 6.9 ft long x 1.8 ft m wide). The chambers are oriented north/south with the front of each chamber facing south. Temperature, CO_2, and relative humidity were controlled and monitored in the airflow to the chambers by a computerized control and data acquisition system. The rooting bins are neither temperature nor CO_2 controlled (Kim et al. 2004). The surface of the rooting medium is in direct contact with the air in the SPAR chamber. Shade cloths are positioned around the edges of the canopy (inside chamber) and raised as the plants grow to simulate the presence and shading of neighboring plants (Reddy et al. 2001).

On May 16, 2001, three weeks after planting seeds in the greenhouse, eastern gamagrass (cv. 'Pete') seedlings of uniform size and development were transplanted into six SPAR chambers. Two rows of eight plants (see Fig. 1) each were transplanted into the rooting bins containing a sand, vermiculite (1:1) mixture. Individual plants and rows were 10 in. apart and 7 in. from the back (north) and front (south) and 10 in. from the east and west ends of the rooting bin. The front row (south row) was 34 in. from the front of the Plexiglas chamber. Plants were numbered from west to east with plants 1 to 8 being on the south (front) side and plants 9 to 16 being on the north (back) side of each chamber (Fig. 1). Plants were fertilized weekly with a complete nutrient solution. Water was supplied by a drip irrigation system 2-3 times a day depending on stage of development. The bottoms of the rooting bins are open allowing free water to drain from the bins. Chambers were controlled at three day/night temperature regimes (68/57, 82/71, and 95/84° F) and two CO_2 levels (370 or 740 $\mu mol\ mol^{-1}$). The thermoperiod was adjusted weekly. Three SPAR chambers were maintained at 370 $\mu mol\ mol^{-1}$ CO_2 at each of the temperature regimes and three chambers were maintained at 740 $\mu mol\ mol^{-1}$ CO_2 (elevated) at each of the temperature regimes (Krizek et al. 2003; Ritchie et al. 2004).

Leaves (shoots > 4 in. tall) were harvested at 8, 16, and 21 weeks for individual plants. Dry weights, number of leaves, and leaf areas for each plant were determined for each harvest. Crowns (shoots 0 to 4 in. tall) and roots were harvested after 21 weeks for the individual plants. Dry weights were determined for all harvests. For the purpose of this paper

means and standard deviations were determined by plant position (i.e., Plant 1, Plant 2) by combining all treatments from the six SPAR chambers since the purpose of this paper was to determine positional effects not treatment effects. One-way ANOVA was used to test significance and Least Significant Difference (LSD) tests were used to determine differences between means by plant positions, plant rows, and plant path at the 0.05 level of probability (Analytical Software 2003). Spatial mapping of biomass was made using Surfer (Golden Software 2002).

Results And Discussion

Out of 96 eastern gamagrass seedlings transplanted to the six SPAR chambers on May 16, two plants died (positions 6 and 14 in SPAR Chamber 6) between week 8 and week 16. One additional plant died (position 7 in SPAR chamber 6) between week 16 and week 21. Shoot, root, and crown weights were measured for the plant in position 7 in SPAR chamber 6 but not for the 21 week harvest of leaf, root and crown for plants in positions 6 and 14 in SPAR Chamber 6. Two of the plants (6 and 7) were on the front row of the chamber while plant 14 was on the back row. Thus 93 of the 96 plants (97%) of the seedlings were alive at the final harvest. SPAR chamber 6 had the highest temperature regime (95/84° F) and highest CO_2 level (740 $\mu mol\ mol^{-1}$). All chambers received the same water and nutrients so chamber 6 should not have had any limiting factors. The high temperature chambers (#3 and 6) had the greatest biomass (Krizek et al. 2003; Ritchie et al. 2004) so it is possible that the increased biomass in chamber 6 may have limited the space available for plants to grow.

Leaf biomass values were significantly lower at the low temperature regime (68/57° F) than at the higher temperature regimes (82/71° and 95°/84° F) for the first harvest (weeks 1-8) but no significant differences among temperature treatments were found in leaf biomass at subsequent harvests (Table 1). Total leaf biomass for the three harvests was significantly higher in the high temperature chamber (95°/84° F) than in the low temperature chamber (68/57° F). Biomass values tended to increase with increased day/night temperature but were not significantly different at the 0.05 level of probability. Total plant biomass values (leaves, crown, and roots) tended to be higher at the higher temperatures but the differences in total plant biomass were not significant. In general, plants grown at high CO_2 level (740 $\mu mol\ mol^{-1}$) tended to have greater total biomass than plants grown at 370 $\mu mol\ mol^{-1}$ CO_2 level; however, these differences were not significant (Krizek et al. 2003; Ritchie et al. 2004).

Since most differences between treatments were not significant, for the purposes of comparing biomass patterns in the chambers, all treatments were combined and handled as a single treatment and comparisons were made based on plant position in the six chambers. Thus, there were six replications of plant position 1, plant position 2, etc. We could then compare results for the sixteen individual plant positions, the two plant rows (south and north), and the eight plant paths (west to east) in the chambers.

There was great variability in biomass among individual plants for the 16 individual positions (Table 2). There was nearly a 50-fold range in total biomass and total leaf biomass between the lowest and highest biomass values and a 70-fold difference in the range for the crown and root biomass. The coefficient of variation ranged from 91 to 98% for the different biomass measurements reflecting the large variability in growth among the 96 plants. Since all plants received the same water by distributed drip irrigation and nutrient supply irrespective of position in the SPAR chambers, it is unlikely that differences in biomass production would have been caused by differences in water and nutrients.

There were significant differences for the different plant parts (i.e., roots, crown, leaves, total plant) depending on whether the plants were on the south (front) or north (back) row of the SPAR chambers (Table 3). The north (back) row of the chambers had significantly higher biomass than the south (front) row. There were also significant differences in biomass variables based on east/west (Path) orientation (Table 4). The paths at the east (plants in positions 8 and 16) and west end (plants in positions 1 and 9) of the chambers had the highest biomass production while adjacent plants (in positions 2 and 10 and positions 7 and 15) have the lowest biomass production. These low biomass values may have been caused by shading from the adjacent larger plants on the east and west ends of the chamber.

A plot of total plant biomass (Fig. 1) shows the patterns in biomass production in the chambers related to plant position. These patterns of biomass production are similar to the patterns in PAR measured inside these same SPAR chambers (Kim et al. 2004). Thus, it appears that the patterns of biomass production in the SPAR chambers reflect the patterns of PAR measured in the chambers although the differences in biomass cannot be directly correlated to the PAR measurements. These differences in plant growth may have also been caused by increased shading and competition by larger eastern gamagrass plants in the high PAR locations in each chamber. Differences could have also been related to high genetic variability reported in the individual plants (Bidlack et al. 1999; Dewald and Kindiger 1994).

Conclusions

Eastern gamagrass plants grown in SPAR chambers showed patterns of biomass production that were related to their position in the chambers. The patterns of biomass production in these chambers were similar to the patterns for PAR measurements made in these same chambers (Kim et al. 2004) with greatest biomass values obtained in locations where PAR measurements were also greatest although no direct comparison could be made. Differences may also be due in part to genetic variability of individual eastern gamagrass plants but the patterns measured in the chambers appear at least partly due to the position of the plant in the chamber. We are not suggesting that SPAR chambers should be not be used for studying plant growth and physiological responses; however, researchers should recognize that there may be positional effects within such chambers that should be considered when making plant measurements on individual plants within a chamber. SPAR chambers are excellent facilities for studying plant growth and physiological responses when used correctly.

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Table 1. Leaf biomass of eastern gamagrass in each chamber (pounds per chamber). Numbers in columns followed by the same letter are not significantly different at the 0.05 level of probability by the LSD test.

Chamber	Leaf biomass Weeks 1-8	Leaf biomass Weeks 9-16	Leaf biomass Weeks 16-21	Total leaf biomass[1] Weeks 1-21	Total plant biomass[2] Weeks 1-21
1 (68/57° F) (370 µmol mol^{-1} CO_2)	0.6 b	1.6 a	1.2 a	3.4 b	6.2 a
2 (82/71° F) (370 µmol mol^{-1} CO_2)	2.3 a	2.0 a	1.2 a	5.5 ab	9.8 a
3 (95/84° F) (370 µmol mol^{-1} CO_2)	3.1 a	2.6 a	1.8 a	7.4 a	10.9 a
4 (68/57° F) (740 µmol mol^{-1} CO_2)	0.6 b	1.6 a	1.2 a	3.5 b	6.3 a
5 (82/71° F) (740 µmol mol^{-1} CO_2)	2.6 a	2.6 a	1.5 a	6.7 ab	11.3 a
6 (95/84° F) (740 µmol mol^{-1} CO_2)	3.0 a	2.5 a	2.1 a	7.6 a	11.1 a

[1]Total leaf biomass is the sum of the biomass values obtained for the three harvests of leaves (>4 in. tall).
[2]Total plant biomass is the sum of the biomass values obtained for the roots, crowns (0 to 4 in. tall), and total leaf biomass.

Table 2. Variability in biomass of eastern gamagrass plants grown (n=96) in SPAR chambers (pounds per plant).

	Root biomass (lb)	Crown biomass (lb)	Total leaf biomass[1] (lb)	Total biomass[2] (lb)
Mean	0.04	0.18	0.36	0.58
Standard Deviation	0.04	0.18	0.34	0.53
Minimum	0.01	0.01	0.03	0.05
Maximum	0.23	0.82	1.49	2.34

[1]Total leaf biomass is the sum of the biomass values obtained for the three harvests of leaves (>4 in. tall).
[2]Total plant biomass is the sum of the biomass values obtained for the roots, crowns (0 to 4 in. tall), and total leaf biomass.

Table 3. Average biomass and standard deviation for eastern gamagrass plants grown in SPAR chambers by row (n=48). Biomass in the same column with different letters is significantly different from each other at the 0.05 level of probability.

	Root biomass (oz)	Crown biomass (oz)	Total leaf biomass (oz)	Total biomass (oz)
1 Front	0.4 ± 0.4 b	2.0 ± 1.8 b	4.5 ± 4.5 b	6.9 ± 6.4 b
2 Back	0.8 ± 0.7 a	3.9 ± 3.3 a	6.9 ±6.0 a	11.7 ± 9.6 a

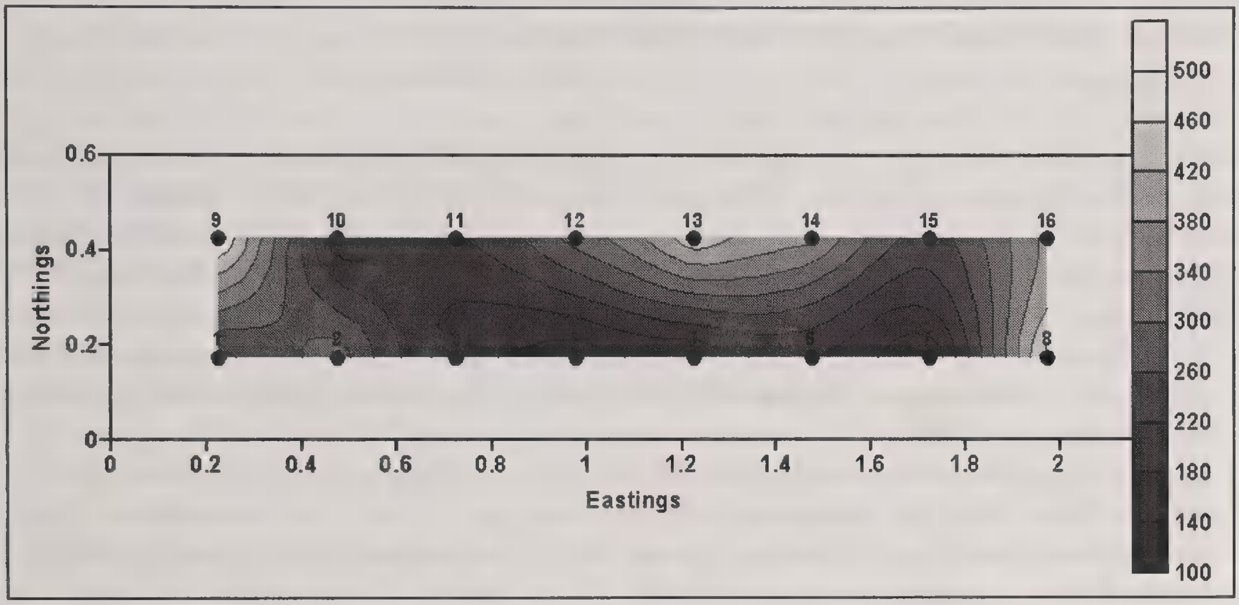
[1]The front row is on the south side of the chamber and the back row is on the north side.

Table 4. Average biomass and standard deviation for eastern gamagrass plants grown in SPAR chambers calculated by path (n=12). Biomass in the same column with different letters is significantly different from each other at the 0.05 level of probability.

Path	Root biomass	Crown biomass	Total leaf biomass	Total biomass	Rank
			ounces		
1 West	0.9 ± 0.8 a	4.6 ± 3.9 a	7.8 ± 7.4 ab	13.3 ± 10.6 ab	2
2	0.4 ± 0.2 b	1.7 ± 0.8 c	3.2 ± 1.7 c	5.2 ± 2.2 c	8
3	0.4 ± 0.5 b	2.1 ± 2.2 bc	3.9 ± 3.7 bc	6.4 ± 6.3 c	6
4	0.5 ± 0.3 ab	2.3 ± 1.5 bc	4.7 ± 3.2 bc	7.5 ± 4.9 bc	5
5	0.8 ± 1.0 ab	3.4 ± 3.9 abc	6.2 ± 6.0 abc	10.3 ± 10.8 abc	3
6	0.6 ± 0.6 ab	3.4 ± 3.7 abc	6.1 ± 6.1 abc	10.1 ± 10.3 abc	4
7	0.4 ± 0.4 b	1.9 ± 1.7 c	3.6 ± 2.7 c	5.9 ±4.6 c	7
8 East	0.9 ± 0.5 a	4.3 ± 2.3 ab	10.1 ± 7.0 a	15.2 ± 9.7 a	1

The front row is on the south side of the chamber and the back row is on the north side.

Figure 1. Overall distribution pattern of total plant biomass (grams per plant: 454 g = 1 pound) within the six SPAR chambers. Numbers along the edge of the rooting bin represent plant position.



Root Growth of Eastern Gamagrass: A Four-Year Study

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Abstract

Eastern gamagrass cv. "Pete" [*Tripsacum dactyloides* (L) L.] was planted in a 100 x 100 ft field in 30-in. rows on May 15, 2002. Twelve minirhizotron access tubes (5 ft long) were installed parallel to the rows at 45-degree angles and installed in pairs either in (in-row) or midway between the rows (between-row). Root images were collected at 0.4-in. intervals to a depth of approximately 40 in. (100 images for each tube). *In situ* images were collected at approximately 1-week intervals in 2002 beginning 1-month after planting, 2-week intervals in 2003, and 3-week intervals in 2004 and 2005 during the growing season using the Bartz minirhizotron imaging system. One month after planting total root occupancy (percent of images from a tube with roots) was 1.5 and 0.0% for in-row tubes and between-rows tubes respectively. By the end of the first year, root occupancy was 45% for the in-rows tubes and 15% for the between-row tubes. Several in-row tubes had roots reaching a depth of 30 to 40 in. At the end of the second year approximately 50 and 40 % of the images for the in-row and between-row tubes, respectively had roots with many reaching 30 to 40 in. depths at the in-row sites. At the end of the third year root occupancy was similar to the second year but the number and size of roots in the images had increased. The fourth year patterns were similar to the third year patterns. This study shows the rapid root develop for eastern gamagrass plants and is suggestive of a fan-like distribution of roots under the developing crowns.

Key words: Eastern gamagrass, *in situ* root measurements, root growth, warm-season grass

Introduction

Eastern gamagrass is a warm-season C_4 grass native to eastern North America (Dickerson et al. 1997). Eastern gamagrass has been used for forage, fuel, and improving acid degraded soil (Clark et al. 1998; Coblentz 1999, Krizek et al. 2003, Foy et al. 1999). It tolerates acid soil conditions and has been shown to grow roots in Al-toxic compact soils (Gilker et al 2001; Foy et al 1999). While many general statements about eastern gamagrass root development are made in the literature (Clark et al. 1998, Gilker et al. 2001), there is limited actual data on eastern gamagrass root development patterns under field conditions. Clark et al. (1996) reported eastern gamagrass roots growing to depths of several yards in Missouri. The roots of eastern gamagrass are expected to live for a period of two to three years before the process of decay begins (Clark et al. 1996). With the increased interest in eastern gamagrass for use a fuel, forage, and soil improvement (Coblentz et al. 1999; Krizek et al. 2003; Ritchie et al. 2006), there has been relatively little research on root growth and development under field conditions. The objective of our research was to investigate *in situ* root growth and development patterns of eastern gamagrass grown under field conditions at the Beltsville Agricultural Research Center, Beltsville, MD.

Methods and Materials

Study Site: Eastern gamagrass seeds, cultivar “Pete”, were planted on May 15, 2002 in a 100x100 ft field on a floodplain soil along Paint Branch Creek on the South Farm at the Beltsville Agricultural Research Center, Beltsville, MD. The soil in the field is mapped as a Codorus-Hatboro complex. The Codorus series (mesic Fluvaquentic Dystrudepts) consists of very deep, moderately well drained to somewhat poorly drained soils. These soils form in recently deposited alluvial materials derived from upland soils materials weathered from mostly metamorphic and crystalline rocks. The Hatboro series (mesic Fluvaquentic Endoaquepts) consists of very deep and poorly drained soils formed in alluvium on floodplains derived from metamorphic and crystalline rock. Slopes at the field range from 0 to 1 percent (USDA 1995).

The field was tilled to 12 in. and roto tilled to 6 in. Seeds used consisted of Germtec™ -treated eastern gamagrass seed that were obtained from Gamagrass Seed Co. (Falls City, NE). These seeds were planted in 30-in. rows using a standard corn planter. The field was irrigated for the first year to insure good germination, stand development, and early growth of the eastern gamagrass. In 2002 and 2003 the eastern gamagrass was harvested using a silage harvester. No harvesting was done in 2004 and 2005 but in February of 2005 and 2006 the residue was burned to remove the previous season's growth. No fertilizer has been added to the field during the study.

Samples for biomass determination were collected using 3-feet strips along rows. Four locations were collected and averaged to determine biomass. Samples were dried in a forced-draft oven at 140° F for 72 hours and weighed to determine biomass.

In Situ Root Measurements: Twelve-minirhizotron access tubes (5 ft long) were installed parallel with the rows at 45-degree angles. The access tubes were installed in pairs with one directly under the row (in-row) and a one adjacent midway between the rows (between-row). In situ images were collected at 0.4-in. intervals in the access tubes to a depth of approximately 40 in. (100 images for each tube) using a Bartz Technology Corporation Minirhizotron Camera System. In situ images were collected at approximately 1-week intervals in 2002 beginning 30 days after planting, 2-week intervals in 2003, and 3-week intervals in 2004 and 2005 using the Bartz minirhizotron imaging system. In situ measurements were made only during the growing season for eastern gamagrass (May to September). No measurements were made during the dormant season. Each image was viewed and a simple presence or absence of roots was determined. These observations were used to determine the “root occupancy' or the percent of images from an access tube that had a root.

Results and Discussion

An excellent stand of eastern gamagrass quickly developed in the field. Average number of tillers per linear foot was 90 on May 15, 2003, one year after planting. Tillers reached heights of 5 to 6 feet in 2003, 2004, 2005, and 2006. Biomass of eastern gamagrass was 1.33, 4.75, 5.28, 3.48 t ac^{-1} for 2002, 2003, 2004, and 2005, respectively. During the first year some annual grasses and weeds also germinated and grew in the field. In subsequent years (2003+) these annual grasses and weeds were not found in the field.

Roots were found during the first *in situ* measurements made on June 13, 2002 at the access tubes in the in-row positions (Fig. 1). It was approximately 50 days after planting before roots were found at the between-row access tubes. Roots at the in-row access tubes increased exponentially for the first 100 days reaching almost 45% occupancy. Roots at the between-row access tubes increased linearly the first 90 days and then had a large increase the last 7 days. Root occupancy only reached about 20% at the between-row access tubes which was less than half that measured at the in-row tubes. While it is not possible to determine where the roots originated during this first 100-day period due to the presence of other annual grasses and weeds, we feel due to the patterns of root development under the eastern gamagrass rows and the persistence of roots at the same place in subsequent years that most of the roots were from eastern gamagrass. Roots were found at 30 to 40 in. in several of the in-row tubes by the end of the first year and most of the tubes in subsequent years.

The pattern of root growth at the in-row tubes over the first 2-years (Fig.2) was rapid during the growing season with root loss during the dormant season and then regrowth of roots followed by root loss during the dormant season. Root occupancy reached 60% by the end of the growing season the first 2-years then dropping to about 40% by the beginning of the next growing season at the in-row tube sites. Years 2004 and 2005 had similar patterns and similar occupancy with smaller losses of roots during the dormant season.

The root occupancy at the between-row tubes was less than that at the in-row tubes and the pattern was different with more roots at lower depths (Data not shown). During the dormant season root loss at the between-row tubes was less apparent or did not happen. Root occupancy at the between-row tubes continued to slowly increase over the 3-year period and was approaching that at the in-row tubes during the fourth year (data not shown).

The images, in general, tend to support the idea of an inverted cone or fan pattern of roots spreading with depth under the eastern gamagrass plants. This idea could help explain the lack of root loss at the between-row since at the between-row tubes there were fewer roots in the surface layers and more large roots at deeper depths while at the in-row tubes there were more roots (mostly small) in the surface layer as well a the large roots deeper in the profile. If the smaller surface roots tend to die during the dormant season while the larger deeper roots persist into another growing season then the in-row tubes would show the drop in root occupancy during the dormant season.

Conclusion

Root growth was rapid under eastern gamagrass with roots reach 30 to 40 in. in one growing season. Root occupancy at the in-row tubes reached between 50 and 60% by the end of the first growing season and has persisted at those levels for the four years. A pattern of root loss during the dormant season and new root growth during the growing season was found at the in-row tubes. The between-row tubes do not show this pattern of root loss and have slowly increased in root occupancy during the study period. This study suggests an inverted cone or fan distribution of roots under the eastern gamagrass plants. This study also shows the rapid development and persistence of roots under eastern gamagrass.

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Figure 1. Root development of eastern gamagrass for the first 100 day after planting at in-row and between-row access tubes. Data are presented as the root occupancy (percent of images at an access tube with a root visible) in the upper 40 in. of the profile. Data are an average of images collected at six minirhizotron access tubes at the in-row and between-row sites.

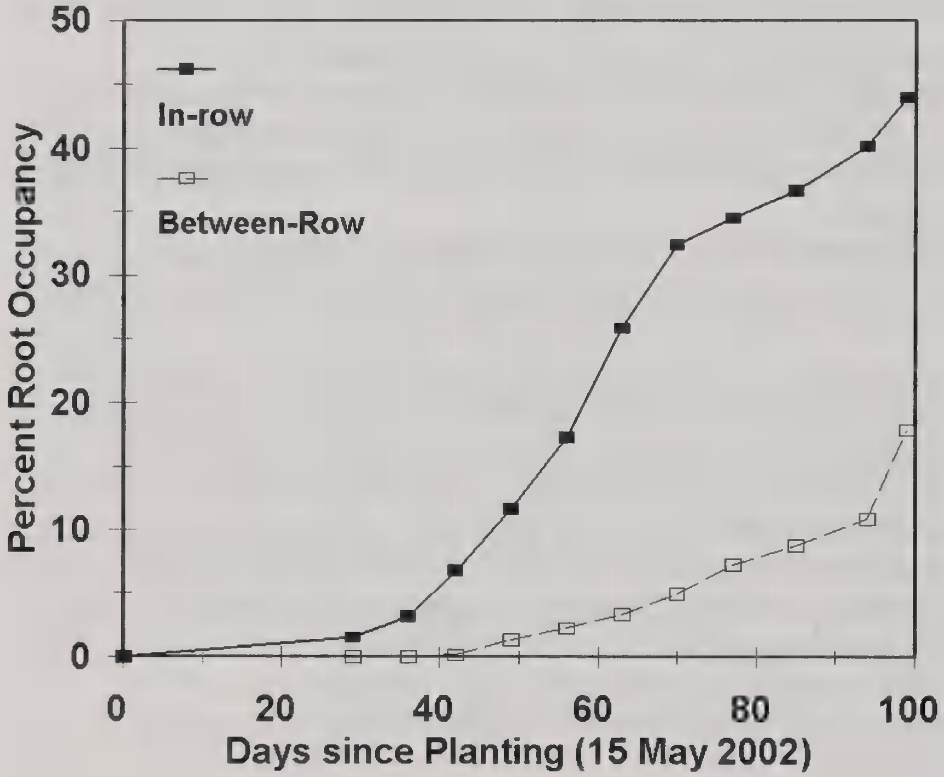
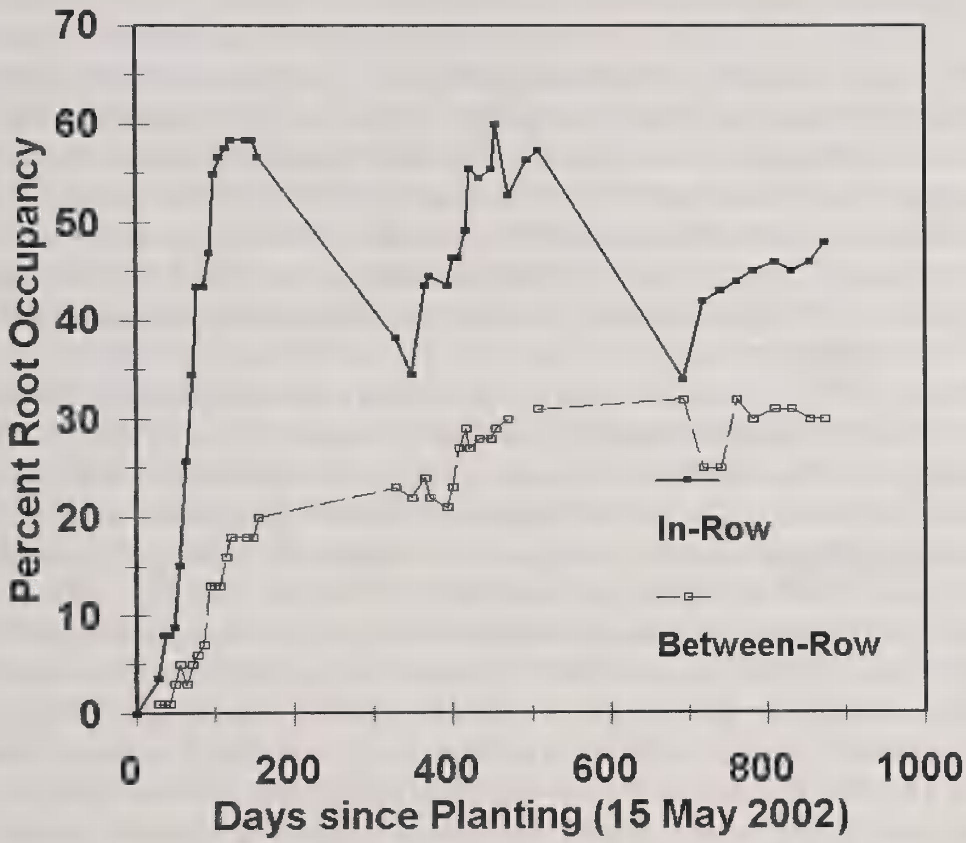


Figure 2. Root development of eastern gamagrass for the first 3 years after planting at in-row and between-row access tubes. Data are presented as root occupancy (percent of images in an access tube with a root visible) in the upper 40 in. of the profile. Data are an average of images made at three minirhizotron access tubes at the in-row and between-row sites.



Production of Eastern Gamagrass Accessions Grown Under Greenhouse Conditions

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Abstract

The development of adapted acid-tolerant plants is important in the southeastern United States. Eastern gamagrass [Tripsacum dactyloides (L.) L.] is a warm-season perennial bunchgrass native to the Midwestern and eastern United States. Eastern gamagrass has been reported to penetrate acidic claypan due to its tolerance of low Ca, high Al and low soil pH. Because eastern gamagrass has high potential productivity and moderate to high forage quality, there is considerable interest in its use as grazed and preserved forage. Reported traits of the species that would be valuable in a sustainable agriculture system include high protein content, high yields, high palatability and digestibility, and peak growth during hot, dry weather when cool-season pasture plants are dormant. As result, eastern gamagrass is being considered as a potential barrier and forage crop in the southeast United States. The objective of this study is to measure the performance of ten eastern gamagrass accessions under greenhouse conditions. Ten eastern gamagrass accessions with varying forage potential were tested to ascertain their performance under greenhouse conditions. Plant height ranged from 29.5 to 50.4 in. and dry matter ranged from 0.2 to 0.4 ounces/pot for the first harvest. Accession six produced the tallest plants on average (47.6 in.) prior to the first harvest. At the second sampling date plant heights ranged from 31.9 to 54.1 in. Accession 3 produced the tallest plants on average (50.3 in.) prior to the second harvest. Plant dry weight ranged from 0.4 to 2.9 ounces/pot. Crude protein ranged from 13.7 to 17.3%. These results indicate that further comprehensive study of these eastern gamagrass populations could identify accession that exhibit specific establishment and growth patterns that are suitable for the southern US.

Key words: Crude protein, forage quality, gamagrass

Introduction

Eastern gamagrass occurs naturally from Massachusetts on the Atlantic coast, west to Nebraska, Oklahoma, and Kansas, and south to Florida and Texas in the United States. It is also found in the West Indies and south to Brazil and Paraguay in South America (Newell and deWet, 1974). Eastern gamagrass is capable of high productivity with moderate to high forage quality. Eastern gamagrass is considered to be a very versatile and widely adaptable grass, and could easily be incorporated into sustainable development programs for marginal lands. And since it closes canopy very rapidly after establishment, it is considered to be very effective erosion deterrent. There is considerable interest in the use of eastern gamagrass as pasture as well as for preserved forage (Krizek et al., 1998).

A major difficulty in developing a sound livestock industry in the southeast has been the lack of adapted grass species with high yield potential. Eastern gamagrass is considered to be tolerant of certain acidic soil types. It has been found to penetrate hardpans and claypans by tolerating acidic Al-toxic soil and/or nutrient solutions in both greenhouse and

field studies (Foy, 1997; Foy et al. 1999; Rhoden et al.2000). There is a growing interest in eastern gamagrass as a forage crop. Burns et al. (1996) in comparing eastern gamagrass with switchgrass and flaccidgrass when preserved as hay found that the hay quality of eastern gamagrass was adequate to meet the energy and protein requirements of many ruminants. Rhoden et al. (2000) obtained crude protein content as high as 19.6% in highly fertilized eastern gamagrass. Eastern gamagrass also shows promise as a dual-purpose grain and forage crop. Eastern gamagrass produces small kernels roughly 6 % the size of corn kernels. Bailey and Sims (2000) estimated the protein content of eastern gamagrass grain to be 30 % as well as having a 90 % grain digestibility. To this end, the Plant Material Centers in the southeast are making progress towards the selection and development of eastern gamagrass cultivars that are suitable for such conditions. These centers and universities are presently screening large populations of eastern gamagrass for suitable ecotypes that are capable of high-quality forage and productivity. Therefore, the objective of this study was to measure the performance of 10 eastern gamagrass accessions under greenhouse conditions and to evaluate its forage potential.

Materials and Methods

This study was conducted in the greenhouse facilities of the George Washington Carver Agricultural Experiment Station, Tuskegee University, Tuskegee, Alabama from 2005 to 2006. Ten accessions of eastern gamagrass were vegetatively established and selected for uniformity. They were arranged in a completely randomized design with three replications. The growth media used in this study a Norfolk sandy loam originating from Alabama (Fine-loamy, kaolinitic, thermic Typic Kandiudult). A day/night temperature of 86/77°F was maintained in the greenhouse for the length of the study. A nutrient solution of 13-13-13 (NPK) was given once biweekly at a rate of 39 pounds per acre. The initial harvest was made when plants where approximately at the boot stage and subsequent harvests every 35 days thereafter. All plants were harvested to 10 in. height, to allow for adequate food reserves to remain without a loss of plant vigor. Data on plant height and vigor was recorded at harvesting for all plants. Data on the amount of shoot growth and regrowth was based on linear measurements and biomass collected for dry matter analysis. The freshly harvested plant parts were rinsed with deionized water, separated, and oven-dried in paper containers at 158°F for 72 hours. After oven drying, samples were placed in desiccators for two hours. Weights were then recorded for total dry matter yield, as well as blade, sheath and stem yields. Samples were then separately ground in a Wiley Mill with stainless steel interior and contact points to pass through a 20-mesh wire screen. The dried samples were then ashed overnight and mineral content determined. Samples of each accession were analyzed for acid detergent fiber (ADF), neutral detergent fiber (NDF), crude protein (CP), total digestible nutrients (TDN) and mineral concentration. Phosphorus, K, Ca and Mg were expressed as percent in tissue. Mineral concentration noted in parts per million (ppm) included: Cu, Fe, Mn, and Zn. Plant micronutrient properties also were determined. Data were subjected to statistical analysis using analysis of variance and where effects were significant ($P < 0.05$) the least significant difference (LSD) was used to separate the means.

Results and Discussion

Accession 6 produced the tallest plants on average (47.6 in.) prior to the first harvest, while Accession 4 produced the shortest plants on average (35 in.). Accession 3 produced

the tallest plants on average (50.3 in.) prior to the second harvest, while Accession 4 produced the shortest plants (36.7 in.). For the third harvest, Accession 3 once again had the tallest plants with an average of 52.8 in., and Accession 5 produced the shortest plants (39 in.) (Table.1). Accession 8 had the lowest overall dry matter production, whereas accession 7 provided the highest total dry matter (TDM) (Table.2). Crude protein ranged from 13.7 % (Accession 2) to 17.3% (Accession 1). Accession 7 contained the highest percent Ca (0.3), and Ca:P (1.0), and the lowest K: (Ca+Mg) (4.1). On the other hand, accession 1 had the lowest Ca concentration (0.2%) and Ca:P (0.4), and the highest K: (Ca+Mg) (7.5). The P concentration ranged from 0.3% (Accessions 5, 6 and 7) to 0.4% (Accession 3), and percent K ranged from 1.7 to 2.1%. Accession 9 had the lowest percent Mg (0.10) while Accession 8 had the highest (0.14%). Percent crude fiber ranged from 32.1% (Accession 2) to 35.3% (Accession 10). Accession 10 had the highest NDF (79%), and Accession 2 the lowest (71%). While Accession 9 contained 38% ADF the ADF of both Accessions 1 and 2 was 33%. Total digestible nutrients ranged from 46.2% (Accession 10) to 50.9% (Accession 2).

The results of this study show that CP of all accessions was well above the 7% needed for brood cows or 10.5% minimum needed for finishing cattle. Therefore, none the accessions would require protein supplementation in order to meet the requirements to maintain growth and development in cattle. Accessions1 and 9, had the highest CP, and would be recommended for feeding, based solely on CP.

It can be speculated that those accessions of medium height with compact stems could be utilized for hay and grazing. The tall, coarser accessions have potential as perennial silage crops on sloping cropland and where soil conditions warrant, would be recommended over corn (Zea mays, L.). These accessions would reduce the need for replanting especially on sloping croplands. Those accessions possessing stiff, erect stems also show promise as vegetative hedges and/or barriers that could reduce runoff and the resultant sediment and nutrient losses.

Acknowledgements

The authors wish to highlight the contributions of Crystal Drakes and Victoria Gaithers of the Tuskegee University Agronomy Laboratory in the completion of this paper.

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Table 1. Plant growth foliage height of 10 eastern gamagrass accessions prior to harvest

Accession	Harvest 1	Harvest 2	Harvest 3	Harvest 4
	----------------------	-inches-	----------------------	
1	41.9	43.2	45.5	43.6
2	41.1	43.4	51.0	45.2
3	44.5	50.3	52.8	49.2
4	35.0	37.7	51.6	41.4
5	39.8	39.4	39.0	39.4
6	47.6	46.6	48.5	47.6
7	47.1	48.4	48.3	47.9
8	37.5	41.2	48.8	42.5
9	36.7	38.7	46.6	40.7
10	39.8	42.8	47.9	43.5

Table 2. Average dry matter production of eastern gamagrass accessions grown under greenhouse conditions

Accession	Harvest 1	Harvest 2	Total yield
	-----------------	-ounces-	-----------------
1	2.45	1.95	4.41
2	2.52	0.97	3.49
3	2.52	1.17	3.69
4	2.21	0.76	2.97
5	2.36	1.80	4.16
6	2.50	2.89	5.38
7	3.11	2.37	5.47
8	2.05	0.55	2.60
9	2.45	1.24	3.69
10	2.24	1.17	3.41

Table 3.Crude protein (CP) and mineral concentration of 10 eastern gamagrass accessions grown under greenhouse conditions

Accession	Crude protein	Ca	P	K	Mg	Ca:P	K:Ca+Mg)
	%	ppm					
1	17.3	0.15	0.39	1.96	0.11	0.38	7.54
2	13.7	0.22	0.38	1.99	0.11	0.58	6.03
3	14.9	0.27	0.44	1.94	0.13	0.61	4.85
4	13.8	0.21	0.33	2.00	0.11	0.64	6.25
5	16.7	0.27	0.30	1.99	0.11	0.90	5.24
6	13.9	0.24	0.30	1.70	0.11	0.80	4.86
7	15.5	0.30	0.30	1.69	0.11	1.00	4.12
8	16.8	0.23	0.40	2.13	0.14	0.57	5.76
9	17.0	0.18	0.35	1.96	0.10	0.51	7.00
10	16.2	0.24	0.33	1.94	0.11	0.73	5.54

Table 4. Crude fiber, neutral detergent fiber (NDF), acid detergent fiber (ADF), and total digestible nutrients (TDN) of eastern gamagrass accessions grown under greenhouse conditions

Accession	Crude fiber	NDF	ADF	TDN
	% of dry matter			
1	32.2	74	33	49.1
2	32.1	71	33	50.9
3	32.9	73	34	49.7
4	33.7	75	34	49.7
5	32.9	73	34	48.6
6	33.3	74	34	49.1
7	32.9	73	36	49.7
8	32.5	72	35	50.3
9	34.5	77	38	47.4
10	35.3	79	36	46.2

Carbon Sequestration and Nitrogen Removal

Nitrogen Usage by 'Medina' and 'Jackson' Eastern Gamagrass

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Eastern gamagrass [*Tripsacum dactyloides (L.)* L.] is a warm-season native perennial grass with potential for forage production. From 1992 to 1994, the USDA-NRCS East Texas Plant Materials Center and Stephen F. Austin State University Agriculture Department conducted a three-year study to evaluate management practices for sustainable production of eastern gamagrass selections in eastern Texas and western Louisiana. 'Medina' and 'Jackson', cultivar releases of the East Texas Plant Materials Center, were compared using clipping intervals of 30, 45, and 60 days and actual nitrogen (N) fertilization rates of 0, 125, 250, and 500 lb/acre on an Attoyac fine sandy loam. Nitrogen removal by 'Medina' and 'Jackson' was calculated using the harvested aboveground biomass. Nitrogen removal by the cultivars varied from 77 to 305 lb/acre depending upon clipping interval and N rate. There was not a significant difference in N removal among clipping intervals. However, N removal differed significantly between N rates. Nitrogen recovery by the cultivars varied from 30.8% to 70.4% depending upon clipping interval and N rate. Yield efficiency of the cultivars varied from 16 lb DM/lb N to 58 lb DM/lb N depending upon N rate and clipping interval. 'Medina' and 'Jackson' could be used in vegetative buffers and phytoremediation of high levels of soil N. Forage producers can attain sustainable levels of forage production while reducing potential N leaching through the soil profile.

Key words: Nitrogen removal, nitrogen use efficiency

Carbon Dioxide Flux During the First Year Following Switchgrass Establishment

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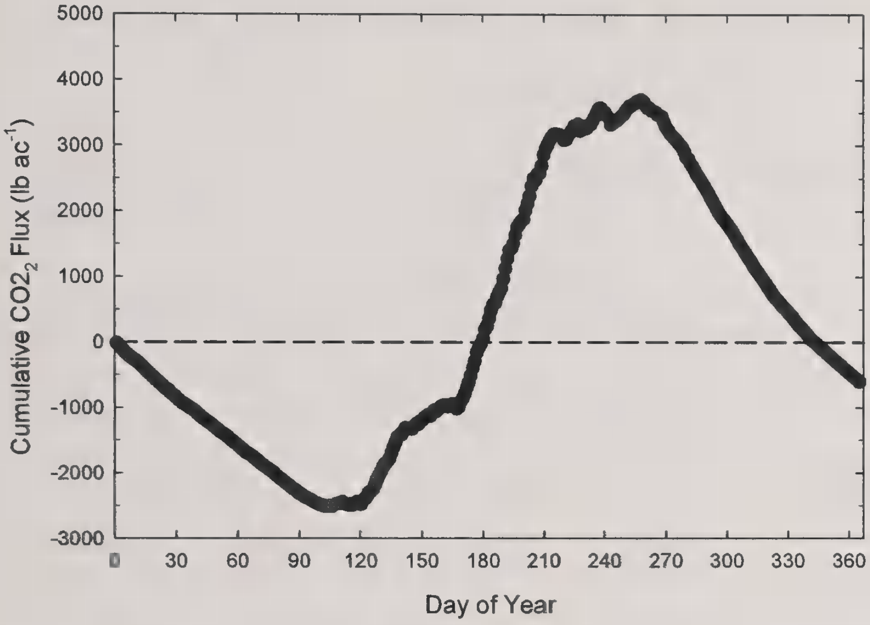
Perennial grasslands managed for biofuel production could provide additional environmental benefits by sequestering carbon in the soil. An eddy covariance flux tower was used to quantify the net CO_2 flux during 2005 for a switchgrass (*Panicum virgatum* L) field that had been planted in 2004. The summer of 2005 was very dry with below normal rainfall during mid-April to late-October. Plots were harvested in April 2006. Poor growth during the summer combined with leaching and lodging losses during the winter resulted in an average yield of only 837 lb dry matter ac^{-1}. The field experienced a net loss of CO_2 due to soil and plant respiration until mid-April when photosynthetic uptake became great enough to offset respiratory losses (Fig. 1). Initial early-season uptake during late-April and early-May was due to weeds since switchgrass did not begin active growth until mid-May. Switchgrass rapidly accumulated CO_2 from mid-June until seed heads appeared in early-August. Little additional net uptake occurred during seed filling. September 15 was the last date that net uptake was observed. Respiratory loss after September 15 offset about 69% of the total uptake during the growing season so that net flux for the year was -603 lb CO_2 ac^{-1}. When the CO_2-equivelent of the biomass removed in April 2006 was subtracted from the total flux, the field became a net source to the atmosphere of 1843 lb CO_2 ac^{-1}. The combination of a dry year and relatively immature switchgrass stand meant that the field was not able to sequester carbon during 2005. Measurements will continue for several more years to determine the carbon sequestration potential of more mature stands under a range of environmental conditions.

Key words: Biofuels, carbon flux, carbon sequestration

Figure 1. Cumulative CO_2 flux during the first production year for a switchgrass field in southern Pennsylvania managed for biofuel production.



Cultivar or Ecotype Development

Cultivar or Local Ecotype, Are We Meeting Customer Needs?

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There is growing interest from the public and private sectors to utilize locally adapted native plant materials for restoration and conservation projects. Many restoration projects are unable to proceed because of the lack of commercially available native plant material. The cultivars that are commercially available are not adapted too much of the state and exhibit signs of summer stress and are less vigorous with lower biomass yields then local ecotypes of the same species. Commercially available sources of locally adapted plant materials have the potential to provide substantial ecological and economic benefits for Louisiana. A major objective of the USDA-NRCS Plant Materials Program is the selection and release of conservation plants. In 60 years, the program has selected over 500 releases of improved conservation plants. However, demand for sources of plants that have no planned genetic manipulation or deliberate selection is increasing. Source identified or ecotype releases are gaining greater acceptance as land managers begin considering the genetic appropriateness of commercially available sources.

The evolving needs of the conservation community must also be balanced with a multitude of other issues facing plant release programs including funding sources, commitment from changing administrations, commercial seed industry support, and the wide range of genetic issues. The Louisiana Native Plant Initiative (LNPI) is a comprehensive plant materials program that will attempt to address the evolving needs of the conservation community by utilizing both local ecotype and cultivar release options. The LNPI will collect, preserve, increase, and study native grasses, forbs and legumes from Louisiana ecosystems, conserving a vanishing natural resource and providing an essential step in the development of a native plant seed industry that will supply plant materials for restoration, revegetation, roadside plantings and the ornamental plant industry. In 2 years, this program has 45 extensive collections from across the state, 15 species in initial evaluation, 5 breeder blocks and 3 species in foundation seed increase. This initiative is a unique partnership between public, private and non profit organizations including the Natural Resource Conservation Service, McNeese State University, Nichols State University, U.S. Geological Survey National Wetlands Research Center, and Coastal Plain Conservancy.

Key words: Conservation plants, genetic appropriateness, Louisiana Native Plant Initiative

New Commercially Available Species and Ecotypes for the Eastern United States

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For 10 to 20 years a diverse array of native species has been available in seed form to restoration practitioners working in the North-Central and Northeastern United States. The species available have included cool and warm-season grasses; legumes; wetland grasses, rushes, and sedges; and upland and wetland wildflowers. Throughout the years, native seed companies have continually added new species to their product lines. Our company has been no exception to this. Table 1 lists the new species by Latin binomial, common name, and ecotypes that should be available by next spring.

The diversity of species available in seed form for restoration projects in the mid-Atlantic and Southeastern U.S. has been far more limited than in the Northeastern and North-Central U.S. In 2000 we embarked upon an aggressive program to bring to commercial availability additional species from these regions. Our efforts were supplemented by members of our grower network. Table 2 lists the new species by Latin binomial, common name, and ecotypes that should be available by next spring.

Key words: Ecotypes,native grasses, restoration

Table 1. List of new plant species and ecotypes available for north central and northeastern U.S. in spring 2007.

Latin Binomial	Common Name	Ecotypes
Agrostis perennans (Walt.) Tuckerman	Autumn Bentgrass	PA
Agrostis scabra Willd.	Ticklegrass	PA
Monarda punctata L.	Dotted Mint	NY (Albany Pine Bush)
Panicum rigidulum Bosc ex Nees	Redtop Panicgrass	PA
Schizachyrium scoparium (Michx.) Nash	Little Bluestem	NY (Albany Pine Bush), PA, CT
Sorghastrum nutans (L.) Nash	Indiangrass	PA

Table 2. List of new plant species and ecotypes available for north central and northeastern U.S. in spring 2007.

Latin Binomial	Common Name	Ecotypes
Agrostis hyemalis (Walt.) B.S.P.	Winter Bentgrass	NC
Andropogon gerardii Vitman	Big Bluestem	NC (Suther)
Carex alata Torr.	Broadwing Sedge	VA
Carex albolutescens Schwein	Greenwhite Sedge	NC
Carex glauscens Ell.	Southern Waxy Sedge	SC
Carex lupulina Muhl. ex Willd.	Hop Sedge	NC
Carex lurida Wahlenb.	Lurid Sedge	NC/VA
Chasmanthium latifolium (Michx.) Yates	River Oats	WV, PA/VA, NC.
Coreopsis grandiflora Hogg ex Sweet	Largeflower Tickseed	GA
Coreopsis tripteris L.	Tall Tickseed	AL
Dalea pinnata (J.F. Gmel.) Barneby	Summer Farewell	FL
Elymus virginicus L.	Virginia Wild Rye	NC (Suther)
Eryngium yuccifolium Michx.	Rattlesnake Master	FL
Glyceria striata (Lam.) A.S. Hitch.	Fowl Mannagrass	NC (Suther)
Helenium autumnale L.	Sneezeweed	FL, VA
Helianthus angustifolius L.	Narrow Leaved Sunflower	NC, SC
Helianthus radula (Pursh) Torr.&Gray	Rayless Sunflower	FL
Hibiscus moscheutos L.	Crimsoneyed Rosemallow	MD, NC, VA
Juncus coriaceus Mackenzie	Leathery Rush	NC
Juncus effusus L.	Soft Rush	FL, NC
Liatris pilosa var. pilosa (Ait.) Willd.	Shaggy Blazing Star	NC
Liatris spicata (L.) Willd.	Spiked Gayfeather	FL
Ludwigia linearis Walt.	Narrowleaf Primrose Willow	SC
Ludwigia maritima Harper	Seaside Primrose Willow	NC
Monarda punctata L.	Dotted Mint	NC, SC
Panicum anceps Michx.	Beaked Panicgrass	FL, GA, NC (Suther), SC, VA
Panicum rigidulum Bosc ex Nees	Redtop Panicgrass	FL and NC
Penstemon laevigatus Ait.	Appalachian Beard Tongue	SC
Penstemon multiflorus Chapman ex Benth.	Manyflower Beard tongue	FL
Rhexia mariana L.	Maryland Meadowbeauty	NC
Rudbeckia fulgida Ait.	Orange Coneflower	FL
Saccharum brevibarbe var. contortum (Ell.) R. Webster	Sortbeard Plumegrass	VA
Saururus cernuus L.	Lizard's Tail	NC
Scirpus cyperinus (L.) Kunth	Woolgrass	NC

Solidago fistulosa P. Mill.	Pinebarren Goldenrod	FL
Solidago odora Ait.	Anisescented Goldenrod	FL
Solidago speciosa Nutt.	Showy Goldenrod	GA
Solidago stricta Ait.	Wand Goldenrod	FL
Sorghastrum nutans (L.) Nash	Indiangrass	GA ("Americus"), NC (Suther)
Tridens flavus (L.) A.S. Hitchc.	Purple Top	FL, GA, NC (Suther), VA
Vernonia angustifolia Michx.	Tall Ironweed	FL
Vernonia gigantea (Walt.) Trel.	Giant Ironweed	FL
Vernonia noveboracensis	New York Ironweed	NC (Suther)

Native Grass Cultivars and Their Adaptations for the Eastern United States

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Abstract

The widespread use of native grasses depends on an inexpensive, reliable supply of seed with dependable growers and known ranges of adaptation. Over the past sixty years, the USDA, Natural Resources Conservation Service, USDA, Agricultural Research Service, State Agricultural Experiment Stations, and private seed companies have developed cultivars of grasses to restore ecosystems and produce forage and wildlife habitat. Each cultivar has a known production capability in the nursery and seed production field as well as the situation into which it is established. Each cultivar has a known range of adaptation to climate, soil characteristics, hydrology, and stress such as grazing within which it will perform. Knowledge of these adaptations has allowed the effective use of these cultivars beyond the area in which they were originally collected. Since the largest market for the tall prairie grasses is in the Midwest, much of the cultivar development has occurred in the states from Texas to North Dakota. Knowledge of the culitvars' adaptations has allowed their use in the eastern part of the United States until more local origins are developed. The poster will present a list of the released cultivars, their intended uses, and range of adaptation.

Key words: Grass characteristics, native grass varieties

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Table 1. Origin, adapation, and special characteristics of released cultivars

	Origin		Adaptation		
Cultivar	State	Plant Hardiness Zone	Plant Hardiness Zone	Major Land Resource Area	Special Characteristics
			Switchgrass (*Panicum virgatum* L.)		
Miami	Florida	10a	8a – 10b	T,U	Adaptation to Florida
Stuart	Florida	9b	8a – 10b	T,U	Adaptation to Florida
Wabasso	Floida	9b	8a – 10b	T,U	Adaptation to Florida
Alamo	Texas	9a	7a – 10b	H,I,J,M,N,O,P.T,U	Lowland Type, Stiff-Stemmed
Kanlow	S. Oklahoma	7a	5a – 8b	H,J,M,N,O,P,S	Lowland Type, Stiff-Stemmed
Carthage	North Carolina	7a	6a – 8b	N,O,P,S,T	Adapted to Eastern Coastal Plain
Blackwell	N. Oklahoma	6b	5a – 7b	D,G,H,J,L,M,N,O,P,R,S	Low Fertility and Water Requirement
Shelter	West Virginia	6a	4a – 7a	L,M,N,O,P,R,S,T	Stiff-Stemmed
Cave-in-Rock	Illinois	5b	4b – 6b	H,M,N,O,P,S	Forage Quality, Grazing Persistence
Shawnee	Illinois	5b	4b – 6b	H,M,N,O,P,S	Selection from Cave-in-Rock, for Forage Quality
Pathfinder	Kansas/ Nebraska	5a	4a – 6a	H,G,M,N,R,S	Late Maturing
Trailblazer	Kansas/ Nebraska	5a	4a – 6a	H,G,M,N,R,S	Forage Quality
Nebraska 28	Nebraska	4b	4a – 5b	H,G,M,N,R,S	Early-Maturing Sandhill Type

	Origin		Adaptation		
Cultivar	State	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	Special Characteristics
Big Bluestem (*Andropogon gerardii* Vitman)					
Suther	North Carolina	7b	7a – 8b	N,P	Local Germplasm
Earl	Texas	7a	7a – 10b	H,I,J,N,O,P,T,U	Long Growing Season
Goldmine	Kansas	5b	4a – 6b	H,J,M,N,O,P,S	Selected from Kaw for Forage Quality
Niagara	New York	6a	4a – 7b	L,M,N,O,P,S	Adapted to Humid East
Kaw	Kansas	5b	4a – 6b	H,J,M,N,O,P,S	Lowland Type, Stiff-Stemmed
Roundtree	Iowa	5a	4b – 6a	M,N,P,S,R	Forage and Seed Production
Bonanza	Nebraska	5a	5a – 6b	D,G,H,J,L,M,N,O,P, R,S	Selected from Pawnee, Forage Quality
Pawnee	Nebraska	5a	5a – 6b	D,G,H,J,L,M,N,O,P, R,S	Earlier Seed Maturity than Champ
Champ	Nebraska	4b	4a – 5b	G,H,L,M,N,R,S	Later Seed Maturity than Pawnee
Indiangrass (*Sorghastrum nutans* L Nash.)					
Americus	Georgia	8a	7b-8b	N,P	Adapted to Humid Southeast
Lometa	Texas	7b	7a – 10b	H,I,J,M,N,O,P.T,U	Best Forage Production in Texas
Suther	North Carolina	7b	7a – 8b	N,P	Local Germplasm
Cheyenne	Oklahoma	6b	5b – 7b	H,M,N,O,P,R,S	Earliest Release
Osage	Oklahoma	6b	4a – 7b	H,M,N,O,P,R,S	Late Maturing
Rumsey	Iowa	6a	4a – 7a	H,M,N,O,P,R,S	Forage Production and Quality
Oto	Kansas/ Nebraska	5a	5a – 6a	H,M,N,O,P,R,S	Earlier Seed Maturity than Champ
Nebraska 54	Nebraska	5a	4a – 5b	H,L,M,N,R,S	Later Seed Maturity than Holt
Holt	Nebraska	4b	4a – 5b	H,L,M,N,R,S	Earlier Seed Maturity than NE-54

Cultivar	Origin		Adaptation		Special Characteristics
	State	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	
Little Bluestem (*Schizycharium scoparium* (Michx.) Nash)					
Suther	North Carolina	7b	7a-8b	N,P	Local Germplasm
Cimarron	Oklahoma/ Kansas	6a	4b – 7a	E,G,H,N,O,P,R,S	Most Recent Release
Pastura	New Mexico	5b	4a – 6b	G,H,M,N,O,P,R,S	Excellent Seedling Vigor
Aldous	Kansas	5b	4a – 6b	F,G,H,M,N,O,P,R,S, T	Medium to Late Maturity
Blaze	Kansas/ Nebraska	5a	4a – 6a	G,H,M,N,R,S	Late Maturing
Camper	Kansas/ Nebraska	5a	4a – 6a	G,H,M,N,R,S	Better Establishment and Forage
Sideoats Grama (*Bouteloua curtipendula* (Michx.) Torr.)					
Haskell	Texas	7b	7a – 9a	H,I,J,N,O,P	Good Rhizome Production
Niner	New Mexico	7a	4a – 8b	D,G,H,N,O,P	Even Seed Maturity
El Reno	Oklahoma	6b	5a – 7b	D,G,H,J,M,N,O,P	Outstanding Forage
Vaughn	New Mexico	6a	4a – 7a	D,E,G,H,N,O,P	Good Drought Tolerance
Butte	Nebraska	4b	4a – 5b	F,G,M,N,R,S	Early Maturing
Trailway	Nebraska	4b	4a – 5b	H,M,N,R,S	Late Maturing
Eastern Gamagrass (*Tripsacum dactyloides* L.)					
St. Lucie	Florida	9b	8a-10b	T.U	Florida Adaptation
Martin	Florida	9b	8a-10b	T,U	Florida Adaptation
Highlander	Tennessee	7a	6b – 8a	O,N,P	Adapted to Humid Southeast
Iuka	Oklahoma	7a	6a – 8a	H,N,O,P,R,S	
Pete	Kansas	6a	5b – 7a	H,M,N,O,P,R,S	First Release

	Origin		Adaptation		
Cultivar	State	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	Special Characteristics
Purple Bluestem (*Andropogon glaucopsis* Ell.)					
Ghost Rider	Florida	9a	8a-10b	T,U	First Release, Adapted to Florida
American Beachgrass (*Ammophila breviligulata* Fern.)					
Hatteras	North Carolina	8a	7a – 9a	T	Better Adapted To South Atlantic
Cape	Massachusetts	7a	5a – 8b	R,S,T	First Release

Coastal Panicgrass (*Panicum amarum var. amarulum* (A.S. Hitchc.&Chase) P.G. Palmer)					
Atlantic	Virginia	7b	5a – 8b	R,S,T	Suitable for Inland and Coastal Use
Bitter Panicgrass (*Panicum amarum* Ell.)					
Southpa	Florida	10a	8a – 10a	T,U	Better Adapted To South Atlantic & Florida Gulf
Fourchon	Louisiana	9a	8a – 10a	T,U	Better Adapted Gulf Coast
Northpa	North Carolina	7a	6a – 8a	T	Better Adapted To Mid-Atlantic Coast
Deertongue (*Dichanthelium clandestinum* (L.) Gould)					
Tioga	Pennsylvania	5a	4a – 7a	L,M,N,R,S	Tolerates ph of 4.0, And Toxic Al and Mn
Virginia Wildrye (*Elymus virginicus* L.)					
Kinchafonee	Georgia	8a	7a – 9a	N,P	Shade Tolerant
Omaha	Nebraska	5b	4b – 6b	*H,L,M,N,R,S*	Shade Tolerant
Maidencane (Panicum hemitomon J.A. Schultes)					
Citrus	Florida	9a	8a-10b	T,U	Shade Tolerant
Halifax	North Carolina	7b	7a-9a	R,S	

	Origin		Adaptation		Special Characteristics
Cultivar	State	Plant Hardiness Zone	Plant Hardiness Zones	Major Land Resource Areas	
Saltmeadow Cordgrass (*Spartina patens* (Ait.) Muhl.)					
Gulf Coast	Louisiana	9a	8a - 10a	T,U	Better Adapted To Gulf Coast
Sharp	Louisiana	9a	8a - 10a	T,U	Better Adapted To South Atlantic & Gulf Coast
Flageo	North Carolina	8a	7a - 9a	T	Better Adapted To Mid-Atlantic Coast
Avalon	New Jersey	7a	6a - 8a	R,S,T	First Release
Smooth Cordgrass (*Spartina alterniflora* Loisel.)					
Vermillion	Louisiana	9a	8a - 10a	T,U	Better Adapted To South Atlantic & Gulf
Bayshore	Maryland	7a	6a – 9b	T	Better Adapted To North & Mid-Atlantic
Seashore Paspalum (*Paspalum vaginatum* Sw.)					
Brazoria	Louisiana	9a	8a - 10a	T,U	First Release, Adapted To Gulf Coast
Seaoats (*Uniola paniculata* L.)					
Caminada	Louisiana	9a	8a - 10a	T,U	First Release, Adapted To Gulf Coast

Ghost Rider Purple Bluestem: A New Conservation Plant with Potential for the Gulf Coast

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Abstract

Developed by the USDA Natural Resources Conservation Service (NRCS) at the Plant Materials Center (PMC) in Brooksville, FL, Ghost Rider purple bluestem [*Andropogon glomeratus var. glaucopsis* (Ell.) C. Mohr] selected germplasm is a native, warm-season, perennial bunch grass. Initial evaluation of purple bluestem was conducted at the USDA-NRCS PMC in Brooksville, Florida, on an assembly of 91 accessions collected from throughout the state of Florida. Transplanted seedlings and direct seeded plants (only 88 accessions) were evaluated for 12 different criteria including plant survival, vigor, plant height, basal width, bloom date, seed maturity date, seed production, and seed viability for 2 and 3 yr, respectively. The 10 accessions that ranked highest in the largest number of criteria over all years of testing were selected to be planted in an increase polycross block to form a composite selected germplasm. Seeds from this crossing block were collected in 2002 and used to establish a breeder seed nursery. Ghost Rider purple bluestem has been assigned the NRCS accession number 9060461.

Key words: Composite germplasm, forage, native species, wildlife habitat

Introduction

Purple bluestem is a native warm-season perennial bunch grass distributed throughout Florida, north to Maryland, and west to Louisiana (Wunderlin and Hansen 2004; USDA-NRCS 2005). Ghost Rider foliage height ranges from 8 to 20 in (20 to 50 cm) and flowering culms from 3.3- to 4.6-ft (100- to 140-cm) tall. Foliage and culms are covered with a chalky, glaucous coating. Culms are purple red between nodes (Yarlett 1996). The leaf blades are folded and keeled at the base and flattened toward the tip, 2- to 4-mm wide; ligules ciliate. Racemes partially enclosed in a purplish-brown spathe, 2 per culm, 0.5- to 1-in (1- to 2.5-cm) long. Spikelet is sessile, 3-mm long with a long straight awn (Hitchcock 1950).

Purple bluestem is one of the most important components of the “flatwoods” ecological community (Soil Water Cons. Soc. Fla. 1987; Yarlett 1996) which is easily recognized by its flat topography and slash pine and saw-palmetto vegetation. Because flatwoods occur on nearly level, poorly drained land, water movement is very gradual to the natural drainageways, swamps, marshes, and ponds associated with this ecological community. During the rainy season, usually June through September, this site may have water on or near the soil surface. The flatwoods community is one of Florida’s most important native range sites and is still widely used by ranchers for cattle production. Other grasses found on flatwood sites include creeping bluestem [*Schizachyrium scoparium* var. *stoloniferum* (Nash) J. Wipff], wiregrass (*Aristida beyrichiana* Trin. & Rupr.), and lopsided indiangrass

[*Sorghastrum secundum* (Ell.) Nash]. Purple bluestem is considered the most palatable native grass in the flatwoods and with poor grazing management will rapidly disappear (Soil Water Cons. Soc. Fla. 1987). In addition to its feed value for cattle, purple bluestem is considered one of the better plants for wildlife, particularly as escape cover and nesting material for bobwhite quail (*Colinus virginianus* L.).

Purple bluestem is a prolific seed producer and readily will colonize disturbed areas in wet flatwoods. No commercial seed source for this species existed and very little information on planting and growing this species under cultivation for seed was known. The objective of this research was to evaluate, develop, and release a Florida variety of purple bluestem for conservation use.

Materials and Methods

Initial evaluation of purple bluestem was conducted at the USDA-NRCS PMC in Brooksville, FL, on an assembly of 91 accessions collected from throughout the state of Florida. An attempt was made to collect three accessions from each county in the state. Collection sites were restricted to at least five miles apart or in completely different ecological zones.

Seeds of these accessions were planted in the greenhouse and plants were transplanted to the field on 10 September 1997, in a randomized complete block with three replications. Each accession was evaluated for survival; foliage height; canopy width; basal width; vigor; resistance to drought; disease and insect damage; culm height; seedhead number; seedhead uniformity; and seed maturity date. Excess seed was available for 88 of these accessions and these were direct seeded (February 1998) in the field on both a well-drained irrigated site (Kendrick fine sand) and a poorly drained irrigated site (Blichton loamy fine sand) that were both relatively weed free. These were evaluated using the same criteria as the transplanted plants.

Ten accessions (Table 1) with superior seed production and growth characteristics were selected from the original 91 accessions to form a synthetic for commercial release. Seeds from the original collections were planted in the greenhouse during April of 2000 to produce seedlings to establish the polycross nursery. These plants were randomly planted in the field in February 2001. One seed harvest was made in the fall of 2001 using a Woodward Flail-Vac Seed Stripper (Ag-Renewal, Inc., Weatherford, OK) run at a high brush speed (Brooksville, FL PMC 2002; Pfaff et al. 2002). Seeds from this harvest were used to establish a foundation seed production field.

Results and Discussion

Previous attempts at the Brooksville, FL PMC and by researchers in other locations had poor success with establishing purple bluestem by direct seeding methods. Emergence for the February 1998 initial evaluation planting was excellent on both irrigated sites. A weed-free seed bed and winter planting date appear to be key factors for successful establishment of this species and is similar to what has been observed with lopsided indiangrass establishment (Brooksville, FL PMC 1998, 2000, 2002).

On the well-drained initial evaluation site, 71 direct-seeded accessions survived and 67 produced seed. Seed germination rates ranged from 4 to 67% with a mean of 31%. On the poorly drained site, 60 accessions survived and 53 produced seed. Germination rates ranged from 0 to 69% and the mean was 31% (Brooksville, FL PMC 1998). Purple bluestem

is often found on the drier sections within flatwoods (Yarlett 1996) and some accessions may have preferred the better drained soils, although this is hard to ascertain from a single planting year.

During these initial evaluations, none of the accessions ranked highest for all evaluation criteria and there was some variation in performance of individual accessions between years. However, several consistently ranked high in several criteria. The ten accessions that ranked highest in the largest number of criteria over all years of testing (Table 2) were selected to form the composite (Brooksville, FL PMC 2002). This composite was assigned the accession number 9060461 and released by the Brooksville, FL PMC in 2006 as a selected germplasm under the name Ghost Rider (Grabowski 2006).

The accessions included in the composite originated from all areas of the state except the southernmost counties below Lake Okeechobee, although purple bluestem has been reported to occur in this region. Ghost Rider purple bluestem should be adapted throughout Florida. It has not been tested at locations outside the state, but chiefly since it is a composite germplasm, it should be useful for restoration work throughout the natural range of the species. It can be planted on lowland sites, such as wet flatwoods, sloughs, and the margins of ponds or marshes. It will not survive on droughty, upland sites without supplemental irrigation. It is well adapted to planting on heavier soil types. An environmental evaluation was completed for this release material to assess its potential to adversely impact the environment. Although there is little available literature on this species, because it is native to the area of intended use, it is thought to pose little risk to native ecosystems.

A limited supply of Generation 1 seed of Ghost Rider purple bluestem will be available in 2006 for commercial producers from the USDA, NRCS Plant Materials Center, 14119 Broad Street, Brooksville, Florida 34601, (352) 796-9600.

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Table 1. Ten superior accessions collected in Florida planted in purple bluestem polycross block at the USDA-NRCS Plant Materials Center, Brooksville, FL.

Accession No.	County (FL)	Collector
9060226	Orange	Fults/Benites/Swims
9060251	Nassau	Gonter/Santucci
9060277	Hardee	Pfaff/Maura
9060318	Brevard	Fults
9060331	Sarasota	Deal/Pfaff
9060340	Bay	Gonter/Santucci
9060347	Taylor	Santucci/Gonter
9060363	Citrus	Gonter/Pfaff
9060394	Polk	Sheehan/Baxter
9060396	Polk	Sheehan/Baxter

Table 2. Evaluation ratings for top ten purple bluestem accession based on performance of transplanted and direct seeded material (poorly drained and well-drained sites) at the USDS-NRCS Plant Materials Center, Brooksville, FL.

		Transplants			Direct seeded					
					Poorly drained site			Well-drained site		
Rank	Accession	Vigor[a]	Seed Prod[b]	Lodge[c]	Vigor	Seed Prod	Lodge	Vigor	Seed Prod	Lodge
1	9060396	3.2	4.3	4.0	4.0	5.0	2.0	4.0	4.5	2.0
2	9060277	4.8	4.5	3.3	3.3	6.0	4.0	3.0	3.0	5.0
3	9060394	3.3	3.8	4.7	4.7	5.0	3.0	5.0	6.0	4.0
4	9060363	4.7	5.5	5.0	5.0	4.0	4.0	4.5	5.0	3.0
5	9060251	4.3	4.5	3.0	3.0	5.5	----	4.0	4.5	4.0
6	9060331	4.7	5.5	4.0	4.0	5.5	----	3.5	4.0	5.0
7	9060318	5.0	5.0	4.3	4.3	4.0	6.5	5.0	5.0	4.0
8	9060226	5.2	5.2	3.3	3.3	5.5	----	4.0	5.0	4.0
9	9060340	5.8	5.5	4.3	4.3	5.5	----	5.0	4.5	5.0
10	9060347	5.7	5.0	5.0	5.0	3.0	4.0	6.0	7.0	2.0

[a, b, c] 1 = excellent, 3 = good, 5 = fair, 7 = poor, 9 = very poor.

Evaluation of the USDA Switchgrass Collection

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The mission of the National Plant Germplasm System (NPGS) is to safeguard plant germplasm that is important to world agriculture by acquiring, documenting, maintaining, distributing and evaluating germplasm. One set of germplasm maintained by the NPGS is the switchgrass (*Panicum virgatum* L.) collection housed at the Plant Genetic Resources Conservation Unit in Griffin, Georgia. The switchgrass collection contains 181 total accessions, 96 percent which are currently available for distribution. The material has been collected from 21 states throughout the U.S. representing a diverse geographic range. Cultivars\releases in this collection include Blackwell, Nebraska 28, Grenville, Kanlow, Maimi, Wabasso, Stuart, Alamo, Shelter, Cave-In-Rock, Caddo, Forestburg, Dacotah, Trailblazer, Shawnee, Sunburst, Falcon, Summer and Pathfinder. The material also includes a great deal of unreleased material. Small seed samples are freely available for bona-fide research purposes and can be requested through the Germplasm Resources Information Network (GRIN) website at http://www.ars-grin.gov/npgs/. The extent of morphological variation and differention in this population of accessions has not been assessed. Typically, descriptor data is available for each accession on the GRIN website. Descriptor data for warm-season grasses include plant height and width, foliage amount, height and distribution, leaf length and width, stem size, tiller production, maturity, seed production and winter survival. To acquire this data for the switchgrass germplasm, all accessions were germinated and transplanted to the field in spring 2006. In the fall 2006, descriptor data will be collected for each accession, and this information will be uploaded to the GRIN website for public access.

Key words: Germplasm, GRIN, NPGS

Progress and Problems in Selecting Six Native Grass Species

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Abstract

The six species currently undergoing selection (switchgrass, indiangrass, little bluestem, big bluestem, purpletop, and beaked panicum) are erect warm-season (C4) perennial bunch grasses. These grasses are native to the plains of North America and are utilized in cultural practices as a source of forage, conservation, habitat establishment, and most recently investigated as a source of biomass for alternative fuels. The objective of this work was to reduce seed dormancy by selecting individual seed that had a reduced dormancy period in laboratory tests and propagate the established seedlings into isolated crossing blocks to progress in reducing dormancy through many cycles. Once the elite individuals are selected they are then taken through several steps in preparation for introduction into the field. While making progress in some species, others are recalcitrant. These problems can be attributed both to cultural practices, and difficulties within the species. The short stature native grasses are not as advanced due in part to the crossing blocks not being completely isolated. In spite of certain precautions seedling mortality is an issue working against success of this research.

Key words: Mortality, seed dormancy, selection

Introduction

Switchgrass (*Panicum virgatum* L.), big bluestem (*Andropogon gerardii* Vitman), indiangrass [(*Sorghastrum nutans* ([L.]) Nash)], little bluestem [*Schizachyrium scoparium* (Michx.) Nash], beaked panicum (*Panicum capillare* L.), and purpletop [*Tridens flavus* (L.) Hitchc.] are warm-season grasses native to the prairie regions of North America (Weaver, 1968). Within these grasses are two categories. The first category includes the tall stature grasses such as: lowland switchgrass, big bluestem, and indiangrass. The second category includes short stature grasses such as upland switchgrass, little bluestem, peaked panicum, and purple top. These C_4 grasses generally begin their annual growth cycle in late spring and are most productive during the mid to late summer months. Almost all important native prairie grasses are cross pollinated by wind and within the cross pollinated progeny, a significant degree of genetic variance exists in both native and cultivated populations (Law and Anderson, 1940; Talbert et al., 1983, Vogel and Pedersen, 1993). This genetic variation endows populations with sufficient diversity to have individuals that grow in a variety of locations within the United States and North America.

The main objective of this project was to use phenotypic recurrent selection to reduce seed dormancy in these native grass species. Reducing the seed dormancy period will allow these grasses to respond quickly to planting, enhancing their role in forage production,

conservation, habitat establishment, and as a source of biomass for alternative fuels. Currently these native grasses are not widely used because producers are cautious in growing a plant species that is so slow to establish. Their slow growth makes them difficult to establish, and poor competitors with weeds, especially annual grasses. This in turn limits their capability of producing enough biomass to accommodate the needs of consumers. In addition, warm-season grasses have traditionally been hard to plant without supplemental cleaning and processing because of hairs and awns found on them. These hairs often make individual seed stick together causing bridging in the planter box, preventing any seed from falling to the ground to be planted. Like many native species, they are known to have extensive seed dormancy, further decreasing stand success. However, once these grasses emerge, other problems arise with establishing the seedlings in subsequent cycles.

Materials and Methods

The classical breeding method of phenotypic recurrent selection was used in an attempt to enhance germination of native populations adapted to the southeastern U.S. The germplasm for the breeding program originated from the "prairie area" with native stands of these species on the USDA-NRCS Jamie L. Whitten Plant Materials Center, Coffeeville MS. The germplasm was selected based on robust vegetative growth and crown size. The plants comprising the mother plant nursery for the tall grass species were dug from the Plant Materials Center and planted at Starkville (as cycle 0). Seed of these plants was screened and used to establish cycle 1 in Starkville. The screening used to evaluate the germination percentages consisted of six petri dishes for each species containing 100 seed per dish. To select the seedlings for the crossing blocks, an estimated 90,000 seed was spread onto fiberglass trays and introduced to the same ideal conditions as the germination procedure. Because we had abundant lowland switchgrass seed from an existing test, seedling selection the first year was very stringent. Seed which germinated in 3 to 4 days were planted, isolated and polycrossed (cycle 1). Such stringent selection was not possible for the other species because seed was limited. Selection for the first cycle of beaked panicum was extremely limited due to poor seed production of the species. Two years of seed was bulked together to obtain enough seed for the selection process to begin.

After the initial screening to produce cycle 1 plants, the plants were established as crossing blocks at the edges of row crop fields to isolate the individuals from others of the same species. When necessary, crossing blocks were surrounded with plantings of sorghum-sudangrass (*Sorghum sudanense* (Piper) Stapf) to isolate them from native pollen. Crossing blocks consisted of a 10 by 10 planting for a total of 100 individuals. Seed produced from cycle 1 plants was subsequently screened for reduced dormancy. The seedlings from cycle 1 with reduced dormancy (germination in <10 days) formed the base population for the cycle 2 population. This process has continued with a total of 5 complete cycles of established lowland switchgrass blocks to date (less for the other species).

Three complete cycles of phenotypic selection has been completed in indiangrass and big bluestem. The same procedures are currently taking place with the short grass species.

Results and Discussion

Advances in germination have been observed in the tall grass species (Table 1). The first year of screening produced germination percentages in lowland switchgrass, big bluestem, and indiangrass at 0.5, 0.33, and 0.33, respectively. The farthest along is lowland

switchgrass. After 4 cycles of selection, the germination percentage for lowland switchgrass has risen from 0.5 (cycle 0) to 48 percent (cycle 2), but declined to 45.8 for cycle 3 and 34.5 for cycle 4. The decline in germination percentages between cycles 3 and 4 is due to our own success. In early generations of selection, we were sure of the first 100 individuals to germinate. The 100 seedlings selected were the first 100 to germinate. However, upon reaching cycle 3, the extremely large number of seedlings to germinate during the first four days of screening has made identification of the next generation parents difficult. As a result, selection of the 100 elite for the next generation was based on seedlings with the tallest first leaf. This is probably not the best method. We have made moderate progress with indiangrass. After 3 cycles of selection, germination of indiangrass seed has increased from 0.33 to 17%. We have made the least progress with big bluestem and have increased germination from 0.33 to 3.16% germination after 3 cycles.

Advancements in the short grass species has been observed in two of the four selected species (Table 1). Purpletop has shown the greatest improvement in germination with an increase from 1.17 (cycle 0) to 15.17 (cycle 2). The other species that had a noticeable increase was switchgrass, which increased from 0.67 (cycle 0) to 4.0% (cycle 1). Little bluestem showed initial progress from cycle 0 to cycle 1, but has stalled in cycle 2. We suspect that the crossing blocks are not truly isolated from native stands and are crossing with these plants. Beaked panicum has yet to show progress in germination percentage. The germination percentage was 0 on seedlings pre-stratification as measured by the germination test. Extremely large numbers of seed were required to obtain 50 for the first crossing block.

Problems/Issues

Problems that have been encountered up to this point include seed and seed production, seedling mortality after emergence, and field planting. Most problems were attributed to sudden environmental changes between locations of maintenance. These sudden changes include: photoperiod, light intensity, and temperature differences. Another problem arises from a lack of maintenance in the crossing blocks from the previous year. If weeds are not kept under control within the crossing blocks the seed from these weeds can be mistakenly collected and counted as emerged seedlings in the laboratory tests. This problem is most often seen in the short stature grasses because most of the annual weedy species are the same height. Tall stature grasses out grow most of the weeds.

Seed /Seed Production

<u>Obtaining enough seed to screen:</u> This is generally not a problem, except in early generations of screening or with especially recalcitrant species. For each species, in each cycle we screen about 90,000 seed per tray. In advanced generations we often get the required 100 seedling from a single tray, sometimes it takes two trays. However, big bluestem and all the short stature grasses required multiple screening trays (seven trays for beaked panicum). Germination testing for the beaked panicum (six replications of 100 seed) showed no pre-stratification germination. It took 2 years to complete the first screening (to collect enough seed to screen).

<u>Seed production all at the same location</u>: At the present time the seed from the short stature grasses in two locations is being compared for germination percentages (cycle 0 in

Coffeeville, cycles 1 and 2 in Starkville). This is a problem because plants at different locations undergo different environmental conditions during seed maturity, making mapping progress difficult. We are currently in the process of cloning mother plants to establish blocks at Starkville so germination percentages for all cycles will be from both locations.

Seed cleanliness: In the early stages of establishment the crossing blocks contain large areas of bare ground which allow weeds to thrive. Crossing blocks must be kept free of weeds and **same-species** seedlings to insure a pure seed lot to screen. As we advance in the cycles of selection, same species seedlings become a greater problem. This is a function of our objectives.

Seedling mortality: Seedling mortality is a major issue. Many seedlings die when transferred from the growth chamber to the potting soil mixture. In an effort to keep seedling from dying post-emergence we took several precautions (listed below). These treatments were effective in some advanced cycle seedlings, but early cycles of selection continued to have post-emergent mortality rates of greater than 40%. We have observed that, as selection progresses seedling mortality declines in advanced generations.

Fungicide treatment: Seedlings would emerge healthy and show signs of fungus after being transplanted into the potting soil mixture in the intermediate growth chamber. To eliminate the fungus, seedlings were germinated in a solution of 0.75% benomyl to keep disease minimal from the growth stages between emergence and transplantation to soil. After transplant the same benomyl mixture was used to saturate the soil cell.

Intermediate growth chamber: We also began to see signs of extensive leaf elongation followed by collapse in newly germinated seedlings. This was believed to be a mechanism of the plants to search for the light that was present in the growth chamber, but not very intense. To resolve this, once emerged, seedlings were placed under conditions with supplemental light banks and reduced temperature and humidity.

Greenhouse conditions: In the early cycles of selection, plants would remain healthy until taken to the greenhouse. At this time mortality rates would be in excess of 45%. This made selection procedures more intensive because instead of selecting 100 plants for a cycle we had to select 200+ plants. After 2 years of watching our plants die we decided that something as simple as extending the photoperiod would ameliorate the stress. Light banks were installed in the greenhouse. Once moved from the 2nd growth chamber, seedlings were taken to the greenhouse and kept under the light bank with a photoperiod consistent with that which would be present at the time field planting (16 hr light).

Nutrients: Every effort was taken to ensure that plants gained biomass quickly. As we began fertilizing on a weekly basis, plants began to show signs of stress. This was quickly diagnosed as ammonium toxicity (common in greenhouse production during winter months in plastic pots). To relieve this toxicity while also meeting fertility requirements of the plants, seedlings were fertilized with a weekly rotation of 20-20-20 and calcium nitrate. The calcium nitrate was used to drive out excess ammonium.

Field planting: Once planted in the field it is important to maintain the crossing blocks.

Watering: As is often the case for Mississippi summers, little to no rain falls. Plants that were not watered on a regular basis were slow to establish and had poor root development. All plants that are transplanted into the field are now on a scheduled daily watering for 2 weeks and fertilized once a week to stimulate roots to move from potting soil into surrounding field soil.

Maintenance: Maintaining a clean crossing block is essential for progress in the breeding program. A weekly check for weeds and emerged same-species seedlings was essential to keep the blocks clean and pure. Poor germination percentages were also thought to be blamed on crossing blocks that were not completely isolated from native stands and other plot work containing the same species. Locations that are determined for crossing block must isolated from the other crossing blocks but in the same geographic location. We foresee this to be a problem in the future as all corners of the farm we plant on have a crossing block already there.

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Table 1. Response of grass species by cycle of selection to reduced seed dormancy (as of 2006).

Grass species	Cycles of selection				
	Cycle 0	Cycle 1	Cycle 2	Cycle 3	Cycle 4
	% germination (No stratification)				
Short Stature					
Beaked panicum	0.0				
Little bluestem	1.3	1.7	1.7		
Purpletop	1.2	1.2	15.2		
Switchgrass- upland	0.7	4.0			
Tall Stature					
Switchgrass- lowland	0.5	27.5	48.0	45.8	34.5
Indiangrass	0.3	2.2	7.5	17.0	
Big bluestem	0.3	1.0	3.3	3.2	

Brooksville Plant Materials Center: Developing Sources of Native Grass Seed for Florida

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Abstract

In Florida, there is a lack of commercial seed sources of native materials for revegetation efforts. This is in part due to the fact that many native Florida species have poor seed production or require management techniques such as burning to produce viable seed. The USDA, Natural Resources Conservation Service (NRCS), Brooksville, FL Plant Materials Center (PMC) initiated a cooperative program with the Florida Institute of Phosphate Research (FIPR) in the 1990s to identify accessions of native species with the greatest potential for commercial seed production. Six seed-producing native grasses were identified in preliminary adaptation trials: Eastern gamagrass (*Tripsacum dactyloides* L.), lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash], purple bluestem (*Andropogon glomeratus* var. *glaucopsis*), hairawn muhly (*Muhlenbergia capillaries* (Lam.) Trin.), switchgrass (*Panicum virgatum* L.), and wiregrass (*Aristida beyrichiana* Trin. & Rupr.). The current focus of the Brooksville Plant Materials Center is to develop reliable seed producing cultivars or germplasm of these grasses and to facilitate their commercial availability.

Key words: Native grass, seed development, revegetation

Introduction

Unlike most of the eastern US which was heavily wooded, when settlers arrived in Florida they were confronted with large areas of native range vegetation (http://wfrec.ifas.ufl.edu/range/rangelands/). The native vegetation on Florida rangelands included grasses, grasslikes, forbs, or shrubs suitable for grazing and browsing use by livestock and wildlife. An overstory of trees was found on some range sites, while others were composed of mostly herbaceous plants. In Florida, "improvements" were often necessitated due to loss of the native vegetation either as a result of deliberate action when alternative industrial or agriculture uses were found, or inadvertently through improper grazing management. In recent years, there has been an increasing interest in both the public and private sectors in revegetating areas in Florida with native species. This is in part due to the perception that native species provide better wildlife food and habitat and offer more sustainable management systems due to lower nutrient requirements. Revegetation with native species is now mandated for much of the phosphate minelands in Peninsular Florida.

By 1999, approximately 300,000 acres of land, or more than 460 square miles, have been mined for phosphate. Wildlife in those areas has suffered because much of this area previously has been revegetated with non-native plant species such as bahiagrass

(*Paspalum notatum* Fluegge) or has become dominated by exotic invasive species such as cogongrass [*Imperata cylindrica* (L.) Beauv.].

Mining operations now are mandated by law to have a reclamation plan that is submitted to the Florida Dep. of Environmental Protection and other local, state and federal agencies for approval. Technical issues associated with reclamation include hydrology, water quality, wetland and other wildlife habitat replacement and mitigation, native vegetation establishment, and exotic weed control. One of the most expensive components of native revegetation projects is the cost of acquiring seed of native species. Due to the lack of commercial seed sources for essentially all Florida native species, current revegetation efforts utilize both mechanical and hand harvested seed from natural stands which by some estimates costs $1000 per acre for the seed alone.

Lack of commercial seed sources for Florida native species is partly due to the fact that many of the Florida native grasses and forbs are poor seed producers, especially those with rhizomatous root systems (Yarlett 1996; Pfaff and Gonter 1996). Also Florida's species evolved under a natural fire regime and some require fairly specific burn timing to produce any quantity of viable seed (Platt et al. 1994). It was apparent, that a systematic approach was necessary to identify the most suitable native species for use on restoration sites and to develop the technology necessary for commercial seed production. In the early 1990's the USDA, NRCS Plant Materials Center in Brooksville, FL, joined with the Florida Institute of Phosphate Research (FIPR) to accomplish this goal. Early work involved the screening of a wide range of native species for growth characteristics and seed production (Pfaff and Gonter 1996). Additionally, much information regarding the management and production of seed from specific Florida native species was developed (Pfaff et al. 2002). As a continuation of this program, the current focus of the Brooksville, FL Plant Materials Center is to develop reliable seed producing cultivars or germplasm of six grasses (eastern gamagrass, lopsided indiangrass, purple bluestem, hairawn muhly, and wiregrass) identified as suitable species for revegetation efforts and to facilitate their commercial availability.

Materials and Methods

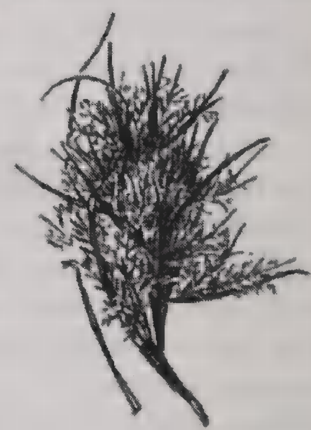
Because this material was to be used over a wide area and not a specific locale (e.g., park or preserve), as wide a genetic range of material of the six different grasses was assembled from within the ecoregion. With the help of local NRCS personnel and the PMC staff, effort was made to locate at least three sources of each of the six grasses in each county in the state with the restriction that the sources be no closer than five miles apart. This resulted in the assembly of between 50 and 150 accessions of each grass species. These accessions were planted in initial evaluation, replicated space plant trials and evaluated for such factors as establishment rate, growth, and seed production for a period of one to four years. At this point, accessions rated as superior were selected and progeny of these superior accessions underwent additional evaluation phases designed to demonstrate heritability of superior characteristics (usually 2 to 3 yr) and to determine range of adaptation (usually 2 to 3 yr).

Due to the demand for native seed, the NRCS, Plant Materials Program has differing release designations that describe the level of testing different plant materials have undergone (Kujawski and Ogle 2005). It is understood that the earlier in an evaluation program a material is released, the greater risk producers and reclamationists assume related to seed production and survival of the material. 'Selected' germplasm is the release

designation for superior material identified after the initial evaluation. If a germplasm is released after the advanced evaluation phase where the heritability of desired characteristics is proven, it receives the classification of 'Tested' germplasm. Only after the superior germplasm has undergone all advanced evaluation phases including regional evaluation trials will it be released under the designation 'Cultivar'.

Results and Discussion

Purple bluestem (*Andropogon glomeratus* var. *glaucopsis*) is one of the most important species found on native range sites and is usually found around water bodies and in wetter flatwoods sites. It is a good seed producer with excellent potential for erosion control, water quality, forage, and wildlife cover. A total of 91 accessions was collected from 43 counties in the fall of 1996. Transplanted seedlings and direct seeded plants (only 88 accessions) were evaluated for 2 and 3 yr, respectively, for 12 different criteria including plant survival, vigor, plant height, basal width, bloom date, seed maturity date, seed production, and seed viability. The 10 accessions that ranked highest in the largest number of criteria over all years of testing were planted in an increase polycross block to form a composite germplasm. Seed from this crossing block was collected in 2002 and used to establish a breeder seed nursery. The material will be released in 2006 as Ghost Rider selected germplasm (NRCS accession number 9060461).



Lopsided indiangrass (*Sorghastrum secundum*) is one of the most easily recognized upland grass species on Florida. It is useful for erosion control, forage, and wildlife and is considered a relatively good seed producer. In 1996, an assembly of 138 accessions was collected from over 48 of the 67 Florida counties. Seedlings were established in both irrigated and non-irrigated replicated plots in 1997. All accessions died after two years at the irrigated site due to an unidentified soil pathogen, but some accessions lived three years in the non-irrigated site. Twenty-five of the top performing accessions were selected and managed as a composite. Seed of this composite material is being increased and is expected to be released as a selected germplasm in 2007.

Eastern gamagrasss is a species that has undergone extensive evaluation and cultivar development throughout the eastern US. It grows on moist fertile sites and is typically found on canal banks or ditches in Florida. An assembly of Florida ecotypes was evaluated in 1996 and 1997. As part of this evaluation, seed was collected weekly during the growing season and the amount of viable seed was determined. Although Florida ecotypes were found to produce seed from June through August, the maximum viable seed amount was found in the last two weeks of August both years. In a multilocation (GA, MS, AL, and TX) evaluation trial, Florida accessions of eastern gamagrass failed to survive the winter period in all locations accept Georgia

and Florida (Douglas et al. 2000). This is because Florida accessions had no real dormancy mechanisms and would begin regrowth too early in the spring to survive. Lack of dormancy does explain the superior forage production associated with Florida accessions in Florida when compared to eastern gamagrass selections originating in more northern locations (Douglas et al. 2000). Accession 9059266 has been identified for release because of its superior forage and seed production. Seed increased is planned for the next two years with anticipated germplasm release occurring in 2008.

Hairawn muhly (also know as muhlygrass) is found on everything from marshy to very dry sites. It has fair seed production and seedling vigor under natural conditions, but under greenhouse conditions muhly seedlings were a constant source of contamination in adjacent pots unless parent plants were trimmed back. Ninety-four accessions of muhly were planted in an initial evaluation trial in 2000. From this population both seed producing and strictly vegetative material has been identified. Because muhly is now widely planted in low maintenance landscaping areas such as road medians, the vegetative material is currently under advanced evaluation for use in the ornamental trade. The seeded selections are scheduled for advanced evaluations with multilocation adaptation trials starting in 2007 and cultivar release in 2010.

Wiregrass can become the dominant grass species in upland communities because of its resistance to fire and its increaser status under grazing. Seed production and seed quality in this species is known to be variable, and fire frequency seems to play an important role in these traits (Kalmbacher et al. 2004). As a consequence direct seeding is not commonly practiced and other techniques for revegetation such as 'greenhay' mulching and transplanting slips are being used. In seedling establishment studies on reclaimed phosphate land, Pfaff and Gonter (2000) found that although lopsided indiangrass had higher initial germination rates, wiregrass seedlings persisted better over a 24-month period than indiangrass planted at the same time. To enhance wiregrass utilization in revegetation efforts, accessions of wiregrass have been collected and will be established in initial evaluation plantings in 2006. These accessions will be evaluated for seed production and seedling vigor under different management strategies including burn frequency, stubble management, and fertility. This program is expected to extend into the next decade.

Switchgrass is perhaps the most widely studied native species in the US. As with eastern gamagrass, switchgrass selections or cultivars originating outside of Florida have proved to be less persistent than selections originating in the state. Seed production has been a problem for Florida accessions. The Brooksville PMC has initiated a cooperative breeding program with the University of Florida to develop seed producing lines of switchgrass based on Florida ecotypes. A statewide collection of switchgrass accessions was made in 2002 and initial evaluation of space plants was conducted in 2003 and 2004. In 2005, remaining accessions were screened to determine ploidy level of the material so superior

accessions of similar ploidy level could be selected and crossing blocks established. The main emphasis of this work, which is expected to extend into the next decade, will be to develop commercially viable seed producing Florida germplasm.

Conclusion

Over the past 15 years, an extensive amount of work has been conducted at the PMC toward the goal of developing commercially viable, seed producing native species for Florida. The pressing need for this material must be balanced with the need for accompanying technology development to ensure successful stand establishment.

Acknowledgments

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Forages and Grazing

Forage Preference of Lactating Does

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Abstract

A choice test study was designed to determine the preference for eastern gamagrass [*Tripsacum dactyloides* (L.) L.] and tall fescue [*Lolium arundinaceum* (Schreb.) S. J. Darbyshire] compared to bermudagrass [*Cynodon dactylon* (L.) Pers.]. Weighed quantities of hay with or without molasses (40cc/lb) were fed to individually housed Boer cross goats. A concentrate supplement (2 lb) was offered daily per doe during the study period and weekly weight changes of the kids were monitored. Results from this study showed significant ($p>0.05$) differences in average daily intake of the three hay types. Although there was a high preference for eastern gamagrass (1.23 lb/day; 1.20 lb/day) and bermudagrass (1.20 lb/day; 1.15 lb/day) with or without molasses, respectively, average daily intake was not significantly different for these two types of hay. However, tall fescue was the least preferred with intake significantly ($p>0.05$) lower than the other two grasses. Addition of molasses did not significantly improve intake for eastern gamagrass and bermudagrass, but intake of tall fescue with (0.84 lb/day) or without molasses (0.71 lb/day) was significantly ($p>0.01$) increased. Average daily gain of kids on these diets was 0.42 lb/day and total gain was 11.6 lb over four weeks. This preliminary result indicates that eastern gamagrass could be substituted in diets for lactating does without any loss in feed intake.

Key words: Bermudagrass, gamagrass, tall fescue, lactating goats

Introduction

Goat production is becoming an important source of income for small-scale limited resource farmers in the southeast USA (Solaiman 2005). Goats eat many forms of vegetation because they are inquisitive, but given a choice; they prefer certain types of forage. This provides the basis to investigate goats' preference for alternative feed sources. Bermudagrass is a warm-season grass commonly used as a pasture grass and as control in feeding trials. Eastern gamagrass is also a warm-season grass but native to southern states and an underutilized resource. It is high yielding and provides good quality forage, with high energy and moderate crude protein content (Rhoden *et al* 2002). Faucette (2005) reported that eastern gamagrass hay supports good growth in meat goats and compares well with bermudagrass in overall weight gains and feed intake. Tall fescue is a cool-season grass found in the North-South transition zones of the U.S. In the upper south, tall fescue provides forage for pasture in late winter through spring and in the fall (Burns and Fisher 2006). It

contains an endophyte fungus (*Neotyphodium coenophialum*) that aids long-term survival of the plant but causes toxicosis in animals (Hill *et al* 1994). Toxicosis is express in part as, reduction in animal performance i.e. reduced weight gains, dry matter intake and digestion. Many reports are available on tall fescue toxicosis in cattle, horses and poultry but limited research information is available on goats. Due to the nature of goats feeding habits, there is a need to explore alternative feed sources. Therefore, the objective of this study was to determine feed preference by lactating adult female goats among eastern gamagrass, bermudagrass and tall fescue fed as hay.

Materials and Methods

The study was a choice test that offered weighed quantities of eastern gamagrass (EGG), bermudagrass (BG) or tall fescue (TF) hay simultaneously with or without added liquid molasses (40cc/lb of hay). Six Boer cross goats (lactating females with kids) were fed for four weeks. Does and their kids were housed in individual pens for a 7 day adaptation period after which they had access to the test diets. Between 0.5–2.0 lb of EGG, BG and TF hay were placed in feeding troughs where both does and kids had access. Treatments consisted of a combination of the three grasses with or without molasses. Concentrate supplement (Nutrena Sweet Stuff ™) was offered at 2.0 lbs/doe/day. Water and salt blocks were available free choice. Records of daily feed intake were kept and expressed as the difference between amounts offered and refused. Weight changes of kids from lactating does were monitored weekly. Data were analyzed as split-split plot design and test of significance was by analysis of variance (AOV).

Results and Discussion

Table 1 shows that there were significant differences ($p>0.01$) in average daily intake by lactating does within weeks and among hay ($p>0.05$) of the trial. Average daily intake for each hay was more than 1.0 lb/doe/day except fescue which was less than one lb. During the first week, intake was highest for eastern gamagrass followed by bermudagrass while tall fescue was the least (Fig. 1). By the second and third week the amount of bermudagrass consumed was similar to eastern gamagrass. However, in the fourth week, intake of bermudagrass was slightly above that of eastern gamagrass. Tall fescue hay was least preferred (0.48–0.98 lb/doe/day) and intake declined after two weeks until the end of the trial (Table 1).

Addition of molasses slightly improved intake for all grasses. When molasses was fed with bermudagrass and eastern gamagrass, a slightly higher intake was noticed than with no molasses (Fig. 2). However, tall fescue with molasses resulted in a higher intake but at a declining rate when compared to bermudagrass and eastern gamagrass (Fig. 1). Significant interactions occurred between weeks x hay and weeks x hay x molasses ($p>0.05$) but the week x molasses interaction was highly significant ($p>0.01$) (Table 1, Fig. 1). Total average daily intake of the different forages offered to lactating does ranged from 3.83 to 4.64 lb/doe/day which was dependent on the combinations offered (Table 2). Kids' average daily gains ranged between 0.36 and 0.46 lb/day but were not significantly different during the trial period (Table 2). It is estimated that 10% of total daily intake by lactating does was converted to meat by their suckling kids (Table 2).

Results from this study indicated that goats prefer and ate more eastern gamagrass and bermudagrass hay than endophyte infected tall fescue when offered at the same time.

Although tall fescue was not readily eaten, it was not totally neglected, but the addition of liquid molasses slightly improved its intake. It is not clear if addition of higher amounts of molasses could make tall fescue hay more acceptable to goats. It is reported that tall fescue plant is associated with an endophyte fungus which produces ergot alkaloids that causes toxicosis in animals (Hill et al 1994). The toxic effect of endophyte infected tall fescue is a factor that reduced feed intake, weight gain and animal performance. Though there was reduced intake of tall fescue hay in this study, the overall total intake by does was not affected. The total average daily intake by lactating does of above 4 lbs. (i.e. 4.22 lbs; combination of all forages offered daily) observed in this study was almost double the values reported by others (Bartlett et al 2005 and Faucette 2005) when either eastern gamagrass or bermudagrass hay was fed to male meat goats as a sole diet. Also, the average daily weight gain by suckling kids of lactating does was twice as much as those reported by these authors (Bartlett et al 2005; Faucette 2005). The presence of other palatable forage species (i.e. eastern gamagrass and bermudagrass) probably masked the toxic effects of tall fescue in this study.

Conclusions

- Eastern gamagrass and tall fescue could serve as alternative feeds for meat goats.
- Tall fescue hay could be fed with other grasses to meat goats with no adverse effects on animal performance.
- A combination of eastern gamagrass and bermudagrass resulted in better performance of lactating meat goats housed in pens as reflected by the kids' weight gains.
- Goats eat many feeds but given a choice they prefer certain forages over others, and eat more of the palatable forages.

Acknowledgement
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Table 1. Average daily intake of bermudagrass, eastern gamagrass and tall fescue hay, with and without molasses by lactating does

	Hay without molasses (lb/doe/day			Hay with molasses (lb/doe/day		
Weeks	[a]EGG	BG	TF	EGG	BG	TF
1	1.21	0.83	0.74	1.23	1.01	0.82
2	1.17	1.22	0.80	1.20	1.23	0.98
3	1.19	1.17	0.80	1.27	1.21	0.90
4	1.24	1.23	0.48	1.23	1.35	0.65
Average	1.20	1.15	0.71	1.23	1.20	0.84
Significance of F test from ANOVA						
Weeks			**			
Hay			*			
Molasses			NS			
Weeks x Hay			*			
Weeks x Molasses			**			
Hay x Molasses			NS			
Weeks x Hay x Molasses			*			

[a]EGG = Eastern gamagrass, BG = bermudagrass, TF = Tall fescue
**, *, and NS = Significant at the 1%, 5%, or not significant, respectively.

Table 2. Average total daily intake of lactating does and weight gains of their kids

Doe	Doe intake	Kid weight gain	Gain from doe's milk
	---lb/day---	---lb/day---	---%---
1	3.92	0.42	10.7
2	4.20	0.45	10.7
3	3.83	0.36	9.4
4	4.64	0.46	9.9
5	4.57	0.44	9.6
6	4.14	0.41	9.9
Average	4.22	0.42	10.0

Figure 1. Interaction of average daily intake of eastern gamagrass, bermudagrass and tall fescue by lactating does

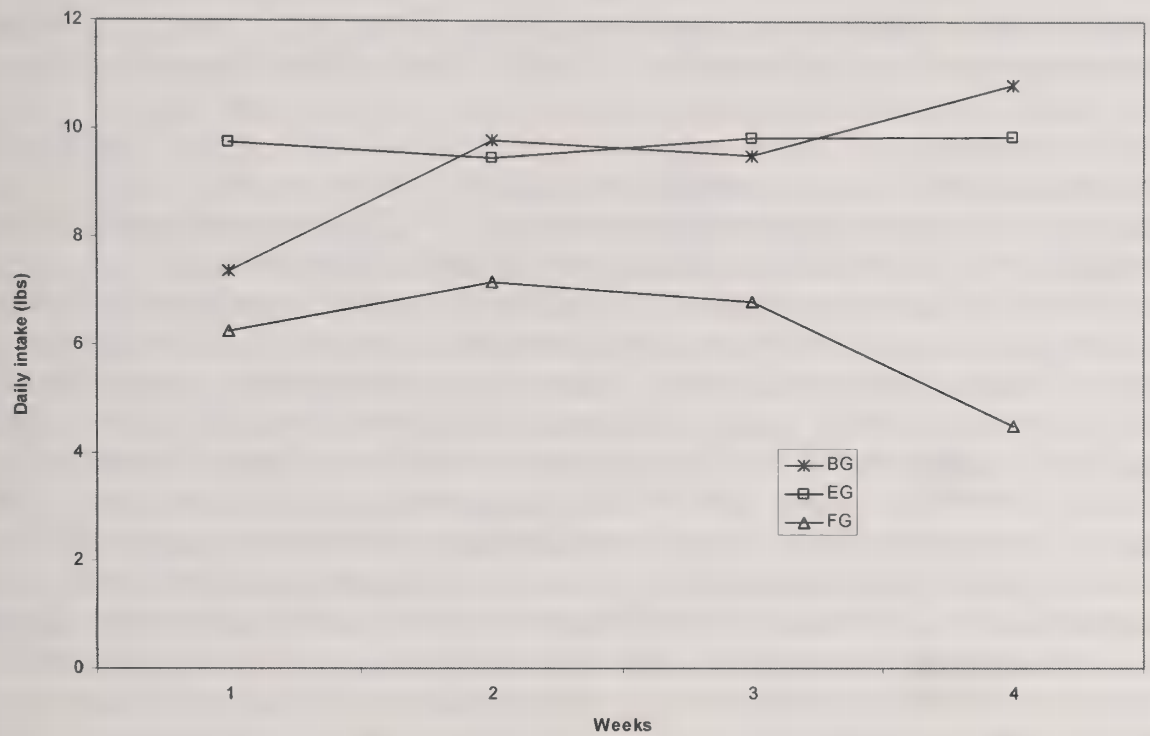
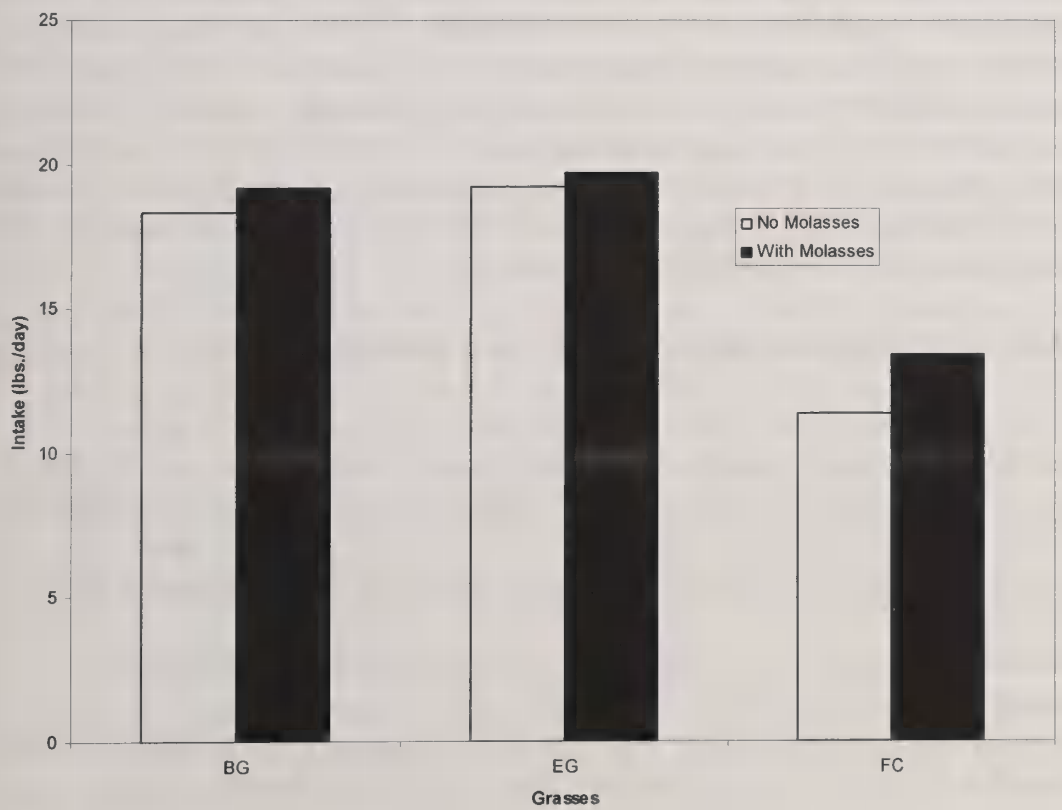


Figure 2. Average daily intake of eastern gamagrass (EG), bermudagrass (BG) and tall fescue (FG) hay with and without molasses by lactating does



Use of a Native Grass in Feeding Trials of Meat Goats

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Abstract

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a native grass that has been adapted as forage. It is a warm-season perennial grass, with high energy and crude protein. Bermudagrass [*Cynodon dactylon (L.) Pers.*] is grown in the South as forage and is a standard for measuring the quality of other grasses. Goat production is an important source of income on small-scale farms in the southeast. Therefore, the objective of this study was to evaluate body weight gain, feed intake, carcass characteristics, and dressing percentages of goats fed eastern gamagrass (EGG) and bermudagrass (BG) hay. The study utilized 12 Boer cross goats (4-5 months old), housed in individual pens and fed one of two treatments: Diet A, 60:40 (EGG: Concentrate), and Diet B, 60:40 (BG: Concentrate), for 13 wks. Water and mineral blocks were provided ad libitum. Feed intake and refusals were monitored daily and feed offered adjusted weekly based on animal weight. Animals were slaughtered at the end of the study period and hot and cold carcass weights recorded. Organ weights were recorded and carcasses were separated into specialty cuts and weighed. Leg circumference and carcass length were measured. There was no significant difference in average daily intake (ADI) for animals on both diets with 2.5 and 2.6 lb/d for diets A and B, respectively. Animals on diet A showed a significant ($P<0.05$) increase in overall body weight gain with 19.0 lb compared to 13.3 lb for diet B. Average daily gain (ADG) was significantly ($P<0.05$) higher for diet A than diet B with 3.3 and 2.3 oz/d, respectively. There were no differences in specialty cuts except for loin which was significantly ($P<0.05$) higher with 18.12% for diet A, and 16.88% for diet B. Kidneys and lungs weighed significantly ($P<.05$) more in animals on diet A than diet B with 1.29 and 0.32% (kidneys), and 0.94 and 0.77% (lungs), respectively. All other organs and parts were not different. Carcass length and leg circumference did not differ between diets. Eastern gamagrass compares well with and in some cases exceeds, the gains obtained from BG, as the results in this study indicated. Eastern gamagrass shows significant potential as high quality alternative forage for meat goats.

Key words: Bermudagrass, carcass characteristics, eastern gamagrass, goats

Introduction

Goat production in the United States is increasing steadily with a recent estimate of 2.9 million head (Ensminger and Parker, 2002). This is mostly attributed to an increase in goat meat (chevon) consumption. This increase is in part due to intensive research comparing the quality of goat meat to other meats (beef, chicken, turkey and pork). It has been shown that goat meat is lower in cholesterol and saturated fatty acids than the other red meats, and with consumers in search of low fat, low caloric, healthful meat sources, they are willing to try new types of meats in an effort to control fat/calorie consumption (Johnston et al. 1995). With this in mind, producers are looking for sources of forages that are of high quality but less expensive than the traditional forages usually fed. Combining that with good

management practices, they can produce animals that can provide them with a good return on their investment. Limited resource farmers especially could utilize nontraditional grasses and legumes that are already available but not much is known about their nutritional quality.

Eastern gamagrass is a rhizomatous, warm-season perennial grass found along the eastern, southern and midwestern states of the US. It is closely related to corn and the two have been known to hybridize (Brown 1979). Eastern gamagrass is one of the more productive, palatable and nutritious native warm-season perennials (Salon and Cherney 1999; NRCS 2002). Forage quality of eastern gamagrass is greatly influenced by harvest dates. Salon and Cherney (1999) showed that crude protein (CP) content of eastern gamagrass harvested in early June was significantly higher than that harvested in late June. These authors also noted that the vegetative stage of the grass had a higher level of CP than the reproductive stage. Most of the previous work done with eastern gamagrass is in cattle. Aikens (1997) working with steers, reported an increase in live weight gain during short duration grazing. When eastern gamagrass seeds were fed along with the hay (Bailey and Simms, 1998), it was reported that the overall digestibility of the ration was increased. Burns et al. (1996), in a study with wethers, noted that the dry matter intake of eastern gamagrass was higher when compared to flaccid grass.

Bermudagrass is most productive during the summer months (Thompson and Thompson 1974) and is commonly fed as forage for beef cattle during the winter months (Stubbendieck et al. 1997; Abdullahi 2002). *In situ* studies on cannulated steers by Scarbrough et al. (2002) estimated the effective degradability of bermudagrass protein in hay vs. pasture. They concluded that during the winter months the level of CP in the hay was higher than the pasture. They also noted that ruminal availability of CP in stockpiled bermudagrass decreased with age but was adequate to meet the minimum requirements of pregnant beef cattle.

Like eastern gamagrass, bermudagrass has higher neutral detergent fiber (NDF) and acid detergent fiber (ADF) than alfalfa (Coleman et al. 2003). These scientists compared bermudagrass hay in the 4 wk stage of cutting to the boot stage of eastern gamagrass hay and found that the eastern gamagrass hay had higher CP values. When these grasses were harvested at the same stage of development, the NDF and ADF values were similar. Coleman et al. (2003) showed that protein digestibility of eastern gamagrass was lower than that of alfalfa and bermudagrass. These researchers also found that the digestibility of NDF and ADF were similar to that of alfalfa and bermudagrass at the early stage of growth. Burns et al. (1996) noted that eastern gamagrass hay provided ideal energy and protein for wethers. Based on digestibility findings and chemical composition, eastern gamagrass could be substituted for bermudagrass in the southern part of the US during the winter months.

Unlike cattle, very little work has been done with goats utilizing eastern gamagrass. In order to evaluate the feeding value of eastern gamagrass as a feed for goats, this experiment was conducted to determine: 1. feed intake and body weight gain of meat goats fed eastern gamagrass and bermudagrass hay; 2. carcass characteristics and dressing percentage of meat goats fed eastern gamagrass and bermudagrass hay.

Materials and Methods

This research was conducted at the George Washington Carver Agricultural Experiment Station Caprine Unit for 13 wks. Twelve Boer bucks were purchased and quarantined for 3 wks prior to the start of the study. The animals were 4-5 months old with an

average body weight of 48.8 lb. The bucks were randomly assigned to one of two diets; Diet A consisted of 60:40 eastern gamagrass:concentrate (Nutrena Sweet Stuff ^{TM}), while Diet B was 60:40 bermudagrass: concentrate. Table 1 shows the chemical composition of the diets used in this experiment. Six goats were randomly assigned to each diet and placed in individual pens. Water and mineral blocks were provided ad libitum. The goats were fed at 5% of their body weight. Feed intake and refusals were monitored daily and feed offered was adjusted weekly. Body weights were monitored on a weekly basis. The animals were slaughtered at the end of the study and hot and cold carcass weights were recorded. Non-carcass components (GI tract, skin, head, liver, heart, lung, testicles, feet, and kidney) were harvested and weighed. The carcasses were separated into specialty cuts and weighed. Carcass length, loin eye area and leg circumference were measured for animals on each diet.

Results and Discussion

Total gain, ADG and Gain/Feed (G/F) ratio were significantly ($P<0.05$) higher in animals receiving the EGG diet (Table 2), with 19.0 lb, 3.3 oz/day, and 0.09 for total gain, ADG and G/F, respectfully. This indicates that goats on this diet were more efficient in converting their feed to weight gain. Burns et al. (1992) compared eastern gamagrass with bermudagrass and flaccid grass and reported significantly higher ADG for steers fed EGG than the other grasses. It should be noted that there were no significant differences in fasted (withdrawal of feed overnight) BW or hot (HCW) and cold (CCW) carcass weights for goats on either the EGG or BG diets (Table 3). Although not significant, goats on Diet A had slightly higher CCW and HCW than those on Diet B with 26.9 and27.3 lb for CCW and HCW, respectively. These results were similar to that reported by Dhanda et al. (2003). These researchers had HCW or CCW between 24.3 and 26.5 lb. Carcass length, leg circumference and loin eye area, which are good indicators of the amount of muscling that the goats put on, were not significantly different between the diets. This is a good indication that EGG compares well with BG and is an excellent alternative forage for meat goats.

Non-carcass components were measured as a percentage of fasted BW and are reported in Table 4. No significant differences were observed for the two diets. The GI tract constituted the largest portion of the non-carcass components with an average of 26.99 and 27.67% for Diets A and B, respectively. These percentages were much higher than that found by Dhanda et al. (2003), who reported a 16.2% average. Specialty cuts were expressed as a percentage of CCW and are reported in Table 5. The loin which is the most expensive cut of meat, was significantly higher ($P<0.05$) in goats from Diet A. Shoulder and leg which are the second most expensive cuts, did not differ significantly between diets. These two cuts comprise over 50% of the total carcass weight and must be considered in the overall economics of chevon production.

Conclusion

Based on the results of this study, eastern gamagrass did as well or outperformed bermudagrass in all the parameters evaluated. This serves as proof that eastern gamagrass shows excellent potential as an alternative forage to be integrated into the feeding programs of meat goats. With producers in the southern United States relying mostly on bermudagrass as their hay source during the winter months, eastern gamagrass can serve as a second

alternative in case of drought or any other force of nature that may prevent a good bermudagrass yield.

Acknowledgements
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Table 1. Chemical composition of bermuda grass, eastern gamagrass and concentrate (Nutrena Sweet Stuff™)

Nutrients	BG	EGG	Sweet Stuff™
Dry Matter (%)	93.44	93.62	92.60
Crude protein (%)	12.38	12.63	13.56
NDF (%)	72.00	68.00	45.00
ADF (%)	36.00	34.00	32.00
TDN (%)	50.31	52.66	55.54
Ca (ppm)	0.35	0.22	1.61
K (ppm)	0.96	2.12	1.18
Mg (ppm)	0.32	0.20	0.34
P (ppm)	0.19	0.24	0.28

BG – bermudagrass, EGG – eastern gamagrass, NDF – neutral detergent fiber, ADF – acid detergent fiber, TDN – Total digestible nutrient

Table 2. Initial and final body weight, weight gain, average daily gain, average daily intake and gain:feed of goats fed eastern gamagrass and bermudagrass

	Diets	
Parameters	A	B
Initial BW (lb)	47.5	51.9
Final BW (lb)	66.5	65.2
Total gain (lb)	19.0	13.3
ADG (oz/day)	3.3	2.3
ADI (lb/day)	2.5	2.6
G/F ratio	0.09	0.05

Diet A – 60:40 eastern gamagrass:concentrate, Diet B – 60:40 bermudagrass: concentrate

Table 3. Fasted, hot and cold carcass weights, carcass length, loin eye area and leg circumference of goats fed eastern gamagrass and bermudagrass

	Diets	
Fasted BW (lb)	A	B
HCW (lb)	60.5	60.6
CCW (lb)	27.3	25.1
Carcass length (in)	26.9	25.1
Loin eye area (in^2)	24.5	24.4
Leg circumference (in)	1.3	1.4
	12.2	12.9

Diet A – 60:40 eastern gamagrass:concentrate, Diet B – 60:40 bermudagrass: concentrate

Table 4. Non-carcass components of meat goats fed eastern gamagrass and bermudagrass (as percent of cold carcass weight)

Parameters	Diets (%) A	B
GI Tract	26.99	27.67
Skin	10.55	10.93
Head	7.78	7.97
Feet	2.84	3.17
Liver	1.39	1.44
Testicles	1.08	1.09
Lung	0.94	0.77
Heart	0.45	0.43
Kidney	0.34	0.33

Diet A – 60:40 eastern gamagrass:concentrate,
Diet B – 60:40 bermudagrass: concentrate

Table 5. Specialty cuts of goats fed eastern gamagrass and bermudagrass(as percent of cold carcass weight)

Specialty cuts	Diets (%) A	B
Ribs	18.27	18.39
Loin	18.12	16.88
Shoulder	20.98	21.17
Neck	10.80	11.17
Leg	32.40	32.47

Diet A – 60:40 eastern gamagrass:concentrate, Diet B – 60:40 bermudagrass: concentrate

Gamagrass Preserved as Hay or Silage for Animal Production Systems

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Abstract

The use of native grasses to improve wildlife habitat is receiving consideration by conservation and wildlife interests. The potential use of native grasses in animal production systems, and particularly as conserved forage, has received little attention. Two experiments in each of 2 yr were conducted to determine the potential utility of gamagrass [*Tripsacum dactyloides* (L.) L.] as conserved forage. 'Pete' and 'Iuka' gamagrass were harvested and compared when preserved as either hay or silage. Both cultivars were readily ensiled with a pH generally ranging from 4.1 to 4.5. Dry matter consumption of the two cultivars conserved as silage did not differ as a percent of body weight per day (% BW/d) and ranged from 1.65 to 1.78 % BW/d among the four experiments. Intake was greater for hay (ranging from 1.89 to 2.03 % BW) compared with silage which ranged from 1.26 to 1.66 %BW/d. Further, dry matter digestion was greater for hay in all four experiments. Consequently, the decision to ensile gamagrass, attractive for risk reduction over hay harvest when faced with adverse weather, warrants careful consideration in light of its reduced quality.

Key words: Gamagrass, hay, quality, silage

Introduction

Housing developments within the rural landscape across the Piedmont of the Southeastern USA has greatly increased the urban-rural interface. Separate, but stimulated by diverse urban-rural life styles, is the growing interest in environmental protection and conservation of native plants and wildlife. Introduced forage species frequently predominate within the grasslands of this landscape. These forages are often natives of Europe and Africa and are generally not well suited for the enhancement of wildlife populations or their diversity. Both urban and rural environmentalists and wildlife proponents often make a point of the poor habitat provided by these introduced species and suggest the reintroduction and establishment of native species of grasses and forbs.

Grasses and forbs that are indigenous to the Piedmont are often favored for wildlife habitat. The potential of native grasses, such as gamagrass, to serve both in animal production enterprises and provide wildlife habitat warrants evaluation. In a production system, native grasses need to be either grazed or harvested and stored as a feed. In a recently completed 5-yr grazing trial, gamagrass stands, depending on grazing intensity, declined over the years (J.C. Burns, ARS and N.C. State University unpublished data). Periodic harvest of gamagrass as hay may prevent stand decline; however, because of the humid environment and relatively frequent rainfall across much of the Piedmont, hay making puts forage quality at risk since humidity and rainfall can degrade the nutritive value and palatability of the hay. A solution to the potential loss of hay due to weather might be the preservation of forage as silage. Generally, however, grasses with C_4 physiology lack

adequate soluble carbohydrates and do not produce a stable product after fermentation (Panditharatne et al. 1986). This problem is partly offset by high dry matter concentration in the forage which reduces clostridia activity (McDonald 1981).

The objectives of this study were to determine the potential of gamagrass to be harvested and stored as silage compared with hay, and to determine if differences occurred between the two available cultivars, Pete and Iuka. Ensiling characteristics of gamagrass were evaluated, as were estimates of dry matter intake and digestion by steers fed either silage or artificially dried hay.

Material and Methods

Well established stands of Pete and Iuka gamagrass served as the source of forage. Growth from the previous fall was burned in late-February and the fields fertilized according to soil test. Nitrogen, as ammonium nitrate, was applied at 80 lb/ac of N in March of the harvest year and applied again after each defoliation and prior to regrowth during the year. At harvest, forage was either flail-chopped and dried for hay, or mowed, windrowed, and immediately chopped and placed in a silo for fermentation.

Methods of Preservation

Hay: The standing forage was direct cut into 3-6 in. lengths using a conventional flail chopper, blown into a self-unloading wagon and elevated into a forced-air dryer with an incoming flue air temperature of 180 °F until dry (> 90%). The hay was baled directly out of the dryer and stored on wood pallets in baled form in a metal building. Hays were fed without further processing.

Silage: Forage for silage was chopped with a field chopper (cut into 0.2 – 0.5 in. lengths), blown into a self-unloading wagon, and packed into experimental silos. Silos were specially constructed fiberglass cylinders (4 ft in diameter x 4 ft in height) with 4 in. flanges on each end. Three of these cylinders were bolted together making a silo 4 ft in diameter and 12 ft in height. The silos were fitted with a 0.l5 mm plastic liner which was tied at the bottom. Forage was elevated into silos and packed by treading as they were filled, and the top of the liner gathered over the silage and sealed. The silo remained sealed for at least 60 d prior to opening.

Four experiments were conducted representing two growing seasons and two harvest dates within each season. Harvest dates are noted below for each experiment.

Intake and Digestion

Beef steers were used in four intake and digestion experiments. The respective range in animal weights for Exp. 1, 2, 3 and 4 were: 505 to 531 lbs, 518 to 576, 620 to 653, and 642 to 699 lbs. Animals were standardized on a common hay diet for 14 d prior to beginning the experiments. Groups of steers were blocked by weight and assigned at random to the appropriate set of treatments within each experiment. Each experimental period of the intake phase consisted of 28 d with the first 14 d used as adjustment and the last 14 d used for intake estimates. Animals were fed a weighed quantity of silage or hay, twice daily, at approximately 115% ad libitum intake. The unconsumed feed (weighback) was removed and weighed prior to each feeding. Daily 'as fed' and 'weighback' samples were obtained for each animal with silage samples stored in freezer until the end of the experiment. The 'as

fed' and 'weighback' samples were mixed, sub-sampled, and the silage sub-samples preserved in the freezer for later analysis.

The digestion phase was conducted in specially constructed crates following the intake phase and consisted of a 7-d adjustment followed by 5 d of total fecal collection. Animals were fed twice daily at approximately 115% ad libitum. The refusals were removed prior to each feeding. Daily 'as fed' feed samples, representing the 5-d fecal collection period, were obtained for each animal, composited for the 5 d (as were the corresponding 'weighback' samples), and preserved in a freezer. The mixed 'as fed' and 'weighback' samples were sub-sampled and returned to the freezer for later analyses.

Laboratory Analyses

The preserved (frozen) silage samples were thawed and a sub-sample used for pH determination after being suspended in water (Fisher and Burns 1987). Concentrations of short-chain fatty acids, alcohols, and lactic acid in silage were determined on aqueous extractions of the samples using gas chromatography. The short-chain fatty acids and alcohols were analyzed using a Nukol fused silica capillary column (48 ft x 0.02 in. x 0.5 μm film thickness, Supelco, Supelco Park, Bellefonte, PA). Lactic acid was determined using a 8 ft glass column (Supelco 4% carbowax 20 M, mesh size 80/120, Carbopack B-DA, Supelco Park, Bellefonte, PA). The remainder of the sample was freeze dried, ground in a Wiley mill to pass a 1-mm screen and the samples scanned in a Near Infrared Reflectance (NIR) Spectrophotometer. Samples with different NIR spectra (determined by H statistic) were analyzed in the laboratory and used to develop prediction equations. In vitro true dry matter disappearance (IVTD) was determined by using nylon bag technology with a batch processor (Ankom Technology., Fairport, NY) followed by extraction with neutral detergent (Van Soest and Robertson 1980). Inoculum was prepared by obtaining rumen fluid from a cannulated steer maintained on alfalfa (*Medicago sativa* L.). Rumen fluid was combined with buffer according to Burns and Cope (1974). Total N was determined by autoanalyzer (AOAC 1990) and multiplied by 6.25 to estimate crude protein (CP). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and cellulose (CELL) were determined sequentially using an Ankom batch processor with reagents (no sodium sulfite) according to Van Soest and Robertson (1980). Lignin was determined using the 72% sulfuric acid method (Van Soest and Robertson 1980). Hemicellulose (HEMI) was determined by difference (NDF – ADF). Dry matter of silage was determined by freeze-drying to a constant weight.

Statistics

The design used in all experiments was a randomized complete block with animals used as replicates. Replicates varied from two to four within and among experiments and between intake and digestion phases within experiments. The data were analyzed using a mixed model. Animal was a random effect and cultivar and preservation method were fixed effects. Because of the expected variation in estimates of animal responses, an *a priori* decision was made to test these variables at $P \leq 0.10$. Variables describing forage composition were tested at $P \leq 0.05$. A set of orthogonal contrasts, consisting of Pete vs. luka (cultivar) and of hay vs. silage (preservation method) and the interaction of cultivar and preservation method were tested in the analysis of variance for each variable.

Results and Discussion

Results from each of the four experiments were analyzed separately and consequently reported by experiment. In each experiment a number of variables showed a significant cultivar by preservation method interaction. In these cases, the interaction was due to a difference in the relative magnitude of treatment effect and not due to reversal of the treatment effect. These interactions were minor and only the main effects reported.

Ensiling Characteristics

Desirable silage is associated with low pH (≤ 4.0) and dominated by acetic and lactic acids, with only trace amounts of butyric acid. This results in silage that is both stable and generally palatable to ruminants. For example, corn silage (one of the more stable and better fermenting grasses) often has a pH < 3.5 and acetic and lactic acid concentrations of approximately 1.3 and 8.5 %, respectively, of the dry matter (McDonald 1981).

In Exp. 1 through 3, both Pete and Iuka, and Iuka in Exp. 4, ensiled well with similar pH ranging from 4.1 to 4.5 (Table 1). This was associated with a predominance of acetic and lactic acids. However, in Exp. 3, lactic acid concentration of Iuka silage was less than Pete silage and associated with the presence of butyric acid which occurred in the silage of both cultivars. Propionic acid was also present in the silages with concentrations greater in Pete than Iuka in Exp. 1 and 2, but least in silage from Exp. 3 and similar in Exp. 4. Methyl and ethyl alcohols were also present in the gamagrass silage but concentrations were similar between cultivars (Table 1).

Forage harvested for silage in May (Exp. 1) or June (Exp. 3) had dry matter concentrations < 19%, whereas forage harvested in late summer (September, Exp. 2 and August, Exp. 4) had dry matter concentrations > 24%. The dry matter of the late summer harvests differed between cultivars with Iuka greatest (Table 1).

Except for Pete in Exp. 4, gamagrass forage was generally well preserved at opening of the silo, however, stability could be an issue if left exposed to the atmosphere after opening as some mold was noted after 24 h.

Nutritive Value

Cultivar: In Exp. 3 and 4, IVTD was greatest for Iuka compared with Pete but Pete was greatest in Exp. 2 and the cultivars were similar in Exp. 1 ($P = 0.06$) (Table 2). Generally, Iuka and Pete did not differ in CP concentrations, except in Exp. 2, in which Pete was greater than Iuka. It should be noted, however, that CP concentrations of the forages in Exp. 1, 2 and 4 are generally inadequate for meeting the growing requirements of steers or heifers. For example, CP concentrations were generally less than the 9.5 to 9.7 % required to support a 600 lb steer or heifer gaining 1.5 lb or more per day (NRC 1984). Pete had greater NDF concentrations than Iuka, except for Exp. 2 in which cultivars did not differ, with similar effects noted for the constituent NDF fractions (ADF, HEMI, Cell and lignin). This is consistent with the lower IVTD reported for Pete in Exp. 3 and 4

Preservation Method: The influence of preserving gamagrass as silage vs. hay varied among experiments for estimates of nutritive value. Preservation methods did not alter IVTD in Exp. 1, but hay was greater in IVTD in Exp. 2 and 4 and silage greater in IVTD in Exp. 3 (Table 2). Crude protein was more consistent with concentrations greatest in silage from Exp. 1, 2 and 4, but not different than hay in Exp. 3. The NDF concentrations were lower in silages for all

four experiments, and is, in part, attributed to lower concentrations of the hemicellulose (Table 2). The ADF and cellulose fraction differed between preservation method in Exp. 1, 2 and 3, but differences were inconsistent. Lignin concentration was altered by preservation method only in Exp. 4 with silage being greatest but the difference was small and of little biological importance.

Animal Responses

Cultivar: Dry matter intake by steers did not differ between cultivars in all four experiments averaging 1.76, 1.78, 1.77 and 1.65 % BW for Exp. 1, 2, 3 and 4, respectively (Table 3). Dry matter digestion, as well as CP digestion, did not differ between cultivars in Exp. 1, 3 and 4, but was least for Iuka in Exp. 2 (Table 3). Digestion of NDF and ADF did not differ between cultivars in all four experiments. An assessment of the digestible intakes (constituent intake x its digestion coefficient) showed cultivar differences in Exp. 2 with digestible dry matter intake and digestible CP intake greater for Pete compared with Iuka.

Preservation Method: The dry matter intake of hay was consistently greater compared with silage in all four experiments (Table 3). On the average, gamagrass hay was consumed at 1.97 % of BW compared with 1.51 for silage. The reduced intake of silage was associated with lower dry matter digestion, including NDF and ADF fiber fractions, and occurred in all four experiments.

Crude protein digestion was variable showing no consistent preservation affects in Exp. 1, 2 and 4, but lower digestion in silage from Exp. 3 (Table 3). Digestible intakes of dry matter, NDF, and ADF were less for silage than hay in all four experiments. Digestible intake of CP, however, was variable with no difference between hay and silage in Exp. 1 and 2, but less for silage than hay in Exp. 3 and 4.

Selective Consumption

Even in conserved crops, animals select the more preferred portions of the feed and reject the less preferred portions and this alters dry matter intake and performance. The degree of selectivity can be determined indirectly by examining the nutritive value of the weighback forage (orts) compared with the offered feed. Selectivity (generally for the leafy fraction and against stems) would be reflected in reduced IVTD and CP, but increased NDF in the measured weighback. In general some degree of selectivity is indicated as the IVTD of the weighback vs. the offered feed (Table 2) was consistently lower for both cultivar and preservation method main effects. This same trend, except for Exp. 2, was also noted for CP. Further, NDF concentrations of the weighback were greater than the fed forage in all experiments, except for Exp. 2.

Cultivar: Generally, the differences in IVTD, CP and NDF of the weighback between cultivars reflect the differences between cultivars in the as-fed forage. Some exceptions are evident, however, as noted especially for CP and NDF in Exp. 3 (Table 2). In these cases more selection occurred for Iuka than for Pete, as the IVTD and CP of the weighback was lower and NDF greater than the differences between the as-fed forage.

Preservation Method: The IVTD, CP and NDF concentration differences of the weighback compared with the as-fed forage generally indicates that more selectivity occurred for the hay

treatment compared with the silage treatment (Table 2). Frequently, in the latter case, the concentrations of the as-fed and weighback were similar.

Summary

Either Pete or Iuka gamagrass can be successfully ensiled and used as a livestock feed. Care is required to assure silage is well packed to exclude as much oxygen as possible to promote anaerobic fermentation to reduce the pH as quickly as possible. Although ensiling of gamagrass provides a way to reduce exposure of harvested forage to adverse weather conditions, the resulting forage is of lower quality than hay without deterioration due to precipitation. Silage dry matter intake was less than hay and the dry matter lower in digestibility resulting in lower digestible dry matter intake. This aspect needs to be given consideration when opting to harvest gamagrass as silage compared to the time required, and risk associated with adverse weather when field curing and handling as hay.

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Table 1. Dry matter (DM) and fermentation characteristics of gamagrass silage harvested at two times during the summer and in two different years (dry matter basis).

			Alcohol[a]		Fatty Acids[b]			
Item	pH	DM	MA	EA	AA	PA	LA	BA
		%						
Experiment 1 (cut May, Year 1):								
Pete	4.1	18.7	0.06	0.23	2.25	0.11	7.26	1.03
Iuka	4.1	18.9	0.07	0.23	2.66	0.06	7.39	0.11
Significance (*P*):	0.84	0.76	0.37	0.98	0.17	0.01	0.92	< 0.01
Experiment 2 (cut September, Year 1):								
Pete	4.4	26.8	0.05	0.18	1.14	0.03	3.84	0.04
Iuka	4.3	30.8	0.05	0.16	1.33	0.02	4.33	0.03
Significance (*P*):	0.07	< 0.01	0.80	0.22	0.06	< 0.01	0.37	0.33
Experiment 3 (cut June, Year 2):								
Pete	4.3	18.3	0.09	0.58	1.83	0.11	5.03	1.58
Iuka	4.5	17.7	0.08	0.47	2.13	0.20	3.75	2.56
Significance (*P*):	0.08	0.30	0.31	0.30	0.52	< 0.01	0.03	0.06
Experiment 4 (cut August, Year 2):								
Pete	6.0	24.8	0.02	0.02	0.17	0.04	0.38	0.09
Iuka	4.4	29.4	0.01	0.13	0.65	0.02	2.55	0.02
Significance (*P*):	0.07	< 0.01	0.33	0.08	0.05	0.06	< 0.01	0.04

[a]MA = methyl alcohol; EA = ethyl alcohol.
[b]AA = acetic acid; PA = propionic acid; LA = lactic acid and BA = butyric acid.

Table 2. In vitro true dry matter disappearance (IVTD) and composition[a] of 'as fed' (AF) forage and weigh back (WB) from four intake experiments comparing gamagrass cultivars and preservation methods (dry matter basis).

Item		IVTD		CP		NDF		ADF	HEMI	CELL	Lignin
		AF	WB	AF	WB	AF	WB	(AF)	(AF)	(AF)	(AF)
		%									
Experiment 1 (cut May, Year 1):											
Cultivar	Pete	64.8	61.7	8.57	6.26	73.0	76.4	41.0	32.1	36.2	4.86
	Iuka	65.9	63.5	8.66	7.81	70.7	72.1	39.8	30.9	34.3	4.95
Significance (*P*):		0.06	0.04	0.49	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.22
Method	Hay	65.5	60.2	8.27	5.31	73.9	78.3	39.6	34.3	34.4	4.90
	Silage	65.2	65.0	8.96	8.76	69.9	70.2	41.2	28.7	36.1	4.91
Significance (*P*):		0.58	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.89
Experiment 2 (cut Sept., Year 1):											
Cultivar	Pete	58.2	56.3	7.58	7.16	73.8	74.7	39.7	34.0	34.6	5.06
	Iuka	56.3	53.7	6.98	7.48	73.5	71.5	40.2	33.3	34.7	5.41
Significance (*P*):		< 0.01	< 0.01	< 0.01	0.60	0.46	0.01	0.08	< 0.01	0.60	< 0.01
Method	Hay	58.1	54.2	6.76	6.67	76.7	76.2	40.3	36.3	35.1	5.14
	Silage	56.3	55.9	7.80	7.97	70.6	70.0	39.6	31.0	34.3	5.33
Significance (*P*):		< 0.01	0.02	< 0.01	0.02	< 0.01	< 0.01	0.01	< 0.01	< 0.01	0.09
Experiment 3 (cut June, Year 2):											
Cultivar	Pete	64.9	63.7	10.19	9.09	71.4	72.9	38.3	33.1	33.9	4.31
	Iuka	66.4	62.1	10.50	7.85	70.5	75.5	37.7	32.8	33.1	4.32
Significance (*P*):		< 0.01	0.02	0.26	< 0.01	0.04	< 0.01	0.09	0.11	< 0.01	0.92
Method	Hay	65.1	61.2	10.38	7.16	73.7	78.3	37.3	36.4	32.9	4.36
	Silage	66.2	64.6	10.30	9.78	68.2	70.1	38.7	29.5	34.1	4.27
Significance (*P*):		0.03	< 0.01	0.76	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.45
Experiment 4 (cut August, Year 2):											
Cultivar	Pete	61.8	57.8	8.78	7.84	70.6	72.9	36.6	34.0	31.8	4.60
	Iuka	64.8	61.6	8.95	7.97	68.4	69.8	35.8	32.6	31.1	4.34
Significance (*P*):		< 0.01	< 0.01	0.21	0.60	< 0.01	< 0.01	< 0.01	< 0.01	0.15	< 0.01
Method	Hay	63.8	59.3	8.44	7.18	71.9	73.8	36.0	35.9	31.2	4.32
Silage		62.8	60.1	9.29	8.62	67.1	68.8	36.4	30.6	31.7	4.62
Significance (*P*):		0.04	0.18	< 0.01	< 0.01	< 0.01	< 0.01	0.06	< 0.01	0.39	< 0.01

[a]DM = dry matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; HEMI = hemicellulose; CELL = cellulose.

Table 3. Dry matter intake and digestion and digestible intakes of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) for two gamagrass cultivars and two preservation methods (dry matter basis).

Item		Intake[a]	Digestion				Digestible Intake[a]			
			DM	CP	NDF	ADF	DM	CP	NDF	ADF
		(% BW/d)	%				% BW/d			
Experiment 1 (Harvested May, Year 1):										
Cultivar	Pete	1.76	54.8	51.4	57.0	58.8	1.01	0.08	0.77	0.43
	Iuka	1.77	55.9	51.4	55.3	56.4	1.08	0.08	0.75	0.43
Significance(*P*):		0.98	0.36	0.99	0.20	0.08	0.43	0.69	0.83	0.80
Method	Hay	2.02	57.8	52.4	60.8	59.4	1.17	0.09	0.90	0.47
	Silage	1.51	52.9	50.4	51.5	55.8	0.92	0.08	0.62	0.39
Significance(*P*):		< 0.01	< 0.01	0.37	< 0.01	0.01	0.03	0.20	< 0.01	0.08
Experiment 2 (Harvested Sept., Year 1):										
Cultivar	Pete	1.76	48.9	47.2	50.5	52.3	0.88	0.06	0.68	0.37
	Iuka	1.79	44.3	34.9	45.8	48.3	0.79	0.04	0.60	0.35
Significance(*P*):		0.74	0.03	< 0.01	0.06	0.09	0.05	< 0.01	0.07	0.20
Method	Hay	1.89	53.3	42.3	56.3	57.0	1.00	0.06	0.81	0.43
	Silage	1.66	40.0	39.8	40.0	43.7	0.66	0.05	0.47	0.29
Significance(*P*):		0.02	< 0.01	0.26	< 0.01	< 0.01	< 0.01	0.31	< 0.01	< 0.01
Experiment 3 (Harvested June, Year 2):										
Cultivar	Pete	1.79	59.3	60.5	62.0	63.8	1.03	0.11	0.78	0.42
	Iuka	1.75	56.2	55.9	59.8	61.4	0.98	0.11	0.73	0.39
Significance(*P*):		0.53	0.32	0.10	0.47	0.46	0.56	0.89	0.51	0.42
Method	Hay	1.93	63.0	63.1	67.6	67.0	1.16	0.13	0.91	0.45
	Silage	1.62	52.5	53.3	54.1	58.2	0.85	0.09	0.59	0.36
Significance(*P*):		< 0.01	0.02	0.01	< 0.01	0.04	0.02	< 0.01	< 0.01	0.06

Table 3(cont'd.). Dry matter intake and digestion and digestible intakes of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and acid detergent fiber (ADF) for two gamagrass cultivars and two preservation methods (dry matter basis).

Experiment 4 (Harvested August, Year 2):										
Cultivar	Pete	1.64	53.8	50.1	57.3	58.6	0.97	0.08	0.72	0.38
	Iuka	1.65	53.7	51.2	54.2	54.5	1.03	0.09	0.73	0.37
Significance(*P*):		0.95	0.98	0.85	0.47	0.35	0.63	0.65	0.97	0.91
Method	Hay	2.03	61.1	55.0	64.4	63.6	1.35	0.10	1.01	0.50
	Silage	1.26	46.4	46.3	47.1	49.6	0.65	0.06	0.39	0.25
Significance(*P*):		< 0.01	0.03	0.21	0.01	0.02	< 0.01	0.03	< 0.01	0.01

[a] % BW/d = percent of body weight per day.

Native Forages on Grazing Lands Conservation Initiative: Working Demonstration Farms in Maryland

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In the mid 1990's the USDA-NRCS through the Grazing Lands Conservation Initiative was dedicated to technical assistance on private grazing lands. Climatic variations continued to show the limitations of introduced cool-season forages as sole sources for livestock forage. The Maryland Grazing Lands Conservation Initiative Coalition made up mostly of innovator farmers, the Maryland Delaware Forage Council, the University of Maryland 's Extension forage program, and the National Plant Materials Center all worked together to investigate, develop and implement a way to jointly utilize each others strengths and facilities to develop native forage usage. Eastern gamagrass (*Tripsacum dactyloides* L.) and switchgrass (*Panicum virgatum* L.) were planted on more than a dozen public and private working farms. Both warm-season forage grasses successfully filled the summer slump and had superior drought resistance to cool-season grasses. Consequently, most of these farmers have permanently included these species in their forage management systems. Eastern gamagrass for grazing, green-chop, and hay was successfully incorporated into management systems of forage based farms. Limited herbicide registration has hampered rapid stand establishment, but with the increased use of dry treated seed to break dormancy, major establishment successes were achieved. Registration of effective herbicides for establishment and maintenance of warm-season grasses is urgently needed. The use of dormant fall plantings was also successful for gamagrass. Stand establishment in companion cropping systems have been only moderately successful, but refinement work continues in this area. The need for a high level of grazing height management has proven necessary to maintain productive stands, but a similar problem exists with introduced species.

Key words: Farms, forages, grazing, herbicides

Eastern Gamagrass, Grazing and Haying

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Introduction

S.B. Farms, Inc. operates a commercial bison herd on the Delmarva Peninsula of Maryland. Eastern gamagrass (EGG) is an integral part of the management intensive rotational grazing system used for the farm. Soil types are generally a sandy loam for this area so without adequate and timely precipitation cool-season grass pastures deteriorate very quickly. Warm-season grass pastures fill in the void during the hot summer months. A native warm-season perennial bunchgrass, EGG has wide leaves with rough edges, grows up to 8 feet tall, and has very good forage nutritive quality. There are several seed companies producing EGG seed. The variety 'Pete' is adapted to our area. Gamagrass is very productive, palatable, and nutritious as a grazed grass. As a hay crop, EGG produces good yields, dries down very quickly, and does not require tedding.

Establishment

We plant EGG with a no-till corn planter using 30 inch rows. Planting is accomplished in the same manner and timing as corn planting with the seed placement depth kept at 1 – 1.5 in. Planter seeding rate is set to provide 3.7 to 4 seeds per foot of row. Field should be void of any other growth at planting – a glyphosate (RoundUp) / 2,4D burndown can be used 2-3 weeks before planting. Normally, lime or fertilizer is not needed the first year. EGG plants should attain a height of 15 to 24 inches the first year.

Management

Control of weeds and grasses in the first year can be accomplished by planting corn interspaced with the EGG rows. In this manner a corn herbicide can be used as a pre-emergence. Perennial cool-season grasses, vetch or other early emerging weeds can be controlled in established stands with controlled burns or by early season applications of glyphosate (RoundUp). Beginning in the second year the EGG can be grazed or hayed based on the grass height and length of time required for re-growth. Apply 60 pounds of nitrogen after each grazing or hay cutting.

Grazing

EGG is very palatable to bison and provides more than adequate nutrition to even the cow/calf herd. Grazing is initiated at about 24 inches of grass height. Care must be taken to not allow grazing to take the EGG plants down shorter than 7 – 8 inches. If an EGG planting is to be used only for grazing it could be established using a drill rather than a corn planter, resulting in 7 – 9 inch row spacings.

Haying

EGG is easy to cut, dry down and bale. SBFI plants EGG in 30 inch rows to accommodate tractor, haybine and baler and wagon traffic. Because EGG is a bunch grass it produces a prominent crown in the second year of establishment. This crown expands in

circumference as the plant ages and prohibits driving over it with a tractor, haybine, baler, or fertilizer spreader. Because of the crowns, EGG is cut in “lands” rather than starting at the field edges and cutting until the center of the field is reached. EGG is cut at seed head emergence (50 – 60 inch height) and the haybine must be set to leave an 8 inch stubble to allow rapid re-growth. Care should be taken to not drive on top of the stubble and crowns as this will crush the remaining plant stems and retard plant re-growth. We have averaged 2.6 tons/acre per cutting with 3-4 cuttings per year.

Key Words: Bison, Eastern Gamagrass, establishment, forage, management

Temperature and CO_2 Effects on Eastern Gamagrass Forage Quality

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Abstract

Future global climates may exhibit increased temperatures and carbon dioxide levels. Climate change effects on forage quality in this native grass species have not been investigated. Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] was grown in sun-lit transparent cuvettes [Soil-Plant-Atmosphere Research (SPAR) chambers] at 370 or 740 µmol mol^{-1} CO_2 and 68/57, 82/71, and 95/84°F day/night temperatures from mid-May to mid-October. Leaves were clipped at 8 and 16 weeks and the whole plants (roots, crowns, leaves) harvested at 21 weeks. Temperature effects on forage quality were more pronounced than CO_2 effects. Leaves grown at 68/57°F had the highest (68%) *in vitro* dry matter digestibility (IVDMD), the least neutral detergent fiber (NDF; 69%), acid detergent fiber (ADF; 34%), and the highest crude protein content (CP; 18%). Growth at 95□F reduced both IVDMD and CP concentration by about 17%. There were no CO_2 effects on leaf CP concentration. We found a slight but consistent effect of CO_2 on forage nutritive value. Across temperature levels, forage from plants grown under the current CO_2 level exhibited slightly higher IVDMD ($P = 0.004$) than that of plants grown under enhanced CO_2 (62% and 61%, respectively) which was associated with enhanced lignin content. The higher protein content of first cuttings of eastern gamagrass, and of eastern gamagrass grown in cooler climates, may result directly from a temperature response in addition to such generally recognized factors as water availability and canopy phenology.

Key words: Forage, nutritive value, *Tripsacum dactyloides*

Introduction

Eastern gamagrass is a tall (6-9 ft) warm-season perennial C_4 bunchgrass native to the Americas and ancestral to corn (Hitchcock and Chase 1950 ; Eubanks 2001). It produces exceptional seasonal forage yields with protein content and palatability comparable to those of high quality alfalfa hay (Horner et al. 1985).

Eastern gamagrass was a primary component of the North American tall grass prairie and occurs in the relatively wet regions of the southern Gulf States (Rechenthin 1951; Eubanks 2001) into semiarid regions of western Texas (Polk and Adcock 1984; Schliesing and Dahl 1983). Natural stands have been decimated through overgrazing and urban development so naturally occurring eastern gamagrass stands are typically restricted to relatively undisturbed areas such as along railroads, fence rows, abandoned roadways or in abandoned fields (Polk and Adcock 1984). Drought tolerance in eastern gamagrass arises from its rooting depth and

the higher water use efficiency characteristic of C_4 plants; eastern gamagrass has one of the highest photosynthetic rates of any C_4 species (Coyne and Bradford 1985). However, a systematic investigation of temperature x CO_2 interactions in eastern gamagrass has not been undertaken.

Given recent concerns of global warming projected to result from anthropogenic greenhouse gases and the reduction of natural plant communities there is considerable interest in photosynthetic carbon sequestration. Models project that CO_2 concentration will continue to increase throughout the twenty-first century, and will increase from current levels (approximately 360 $\mu mol\ mol^{-1}$) to between 540 and 970 $\mu mol\ mol^{-1}$. It is generally accepted that two features of future global climate will be increased CO_2 levels and global temperatures (Wigley and Raper 2001; Forest et al. 2002). Plant ecophysiological effects of CO_2 and temperature have been studied but grasses have received less attention (Wand et al. 1999; Newman et al. 2001). Information on the response of forage quality is accumulating, but investigations of the nutritive and compositional responses of C_4 forages remain sparse (Wand et al.1999; Campbell and Stafford Smith 2000).

The goal of this study was to evaluate atmospheric temperature and CO_2 effects on eastern gamagrass forage nutritive value under variable ambient levels of photosynthetically active radiation.

Methods

Three week old greenhouse grown eastern gamagrass (cv Pete) seedlings were transplanted into a sand-vermiculite mix (1:1, v:v) in six sun-lit Soil-Plant-Atmosphere-Research (SPAR) chambers consisting of large (7 ft x 4 1/2 ft x 8 ft: L x W x H) transparent acrylic cuvettes mounted on 34 ft^3 (6 1/2 x 1 1/2 x 3 1/2 ft : L x W x H) soil-bins (Gitz et al. 2003). The chambers were maintained at 68/57, 82/71, and 95/84°F (±0.4°) day/night at either 370 or 740 $\mu mol\ mol^{-1}$ CO_2 (±10 $\mu mol\ mol^{-1}$). Each chamber held 16 plants (two rows of eight plants) spaced at 10 in. Plants were drip irrigated 2 or 3 times daily with increasing frequency and duration of irrigation events as plants developed. Nutrition was by weekly 20-gallon drenches of a modified Hoagland's nutrient solution (Robinson 1984).

Forage was clipped 4 inches above the soil at 8, 16, and 21 weeks. Samples were dried at 150°F, ground to pass through a 10-mesh screen, stored and subsequently sub-sampled, mixed, and reground to pass a 20 mesh screen. Total carbon and nitrogen of forage from each plant were determined by combustion (Bremmer 1996; Nelson and Sommers 1996). Samples from four plants were pooled and neutral detergent fiber (NDF), acid detergent fiber (ADF), and lignin determined by a modified fiber bag method in which sodium sulfite was eliminated and triethylene glycol substituted for 2-ethoxyethanol to control foaming (Goering and Van Soest 1970; Vogel et al. 1999; Cherney 2000). Lignin was corrected for residual minerals by ashing at 850°F. In vitro dry matter digestibility (IVDMD) was determined using standard methods (Tilley and Terry 1963; White et al. 1981).

Data were treated as for randomized plots with two CO_2 treatments and three temperature levels. For presentation means and standard errors were plotted rather than presenting data in tabular format. Means were obtained with LSMEANS and separated by Tukey's HSD range procedure. Analysis of variance (ANOVA) was by the general linear models procedure (SAS 8.3, SAS Institute 1993).

Results

As temperature, CO_2 concentration, and harvest date increased, forage nutritive value decreased (Figure 1). Forage from plants grown at the lowest temperature (68/57°F) had the lowest ADF and lignin and the highest IVDMD and nitrogen concentration. Later harvests were higher in ADF and lignin which was associated reduced IVDMD. The response of forage fiber components (NDF, ADF and lignin) to temperature was non-linear. At 81.5°F NDF, ADF and lignin were disproportionately enhanced. At first harvest NDF, ADF and lignin increased by 10, 27 and 54% respectively at 82/71°F but only 6, 25 and 32% at 95/84°F. Across harvest dates, nitrogen content decreased with temperature (Figure 2) from about 2.9% at 68/57°F to 2.4% at the two higher temperatures (82/71°F and 95/84°F). The carbon to nitrogen ratios exhibited a pattern similar to that of fiber content (Figure 1), but this was associated with relative nitrogen content (Figure 2).

The effect of CO_2 on leaf fiber and nitrogen content was significant (Table 1), but small compared to temperature effects (Figures 1 and 2). On average, forage from plants grown at the current CO_2 level was only very slightly more digestible (IVDMD about 62%) than that of enhanced CO_2 grown plants (IVDMD about 61%). CO_2 effects on forage quality were associated with increased mean NDF, ADF and lignin content (Figure 1). No clear CO_2 effect on carbon or nitrogen content was found (Figure 2, Table 1).

Harvest date affected all measured forage characteristics (Table 1). Younger plants were more responsive to temperature and CO_2. The greatest differences were found early in the season, at the first harvest (Figures 1 & 2) resulting in significant temperature x harvest date interactions (Table 1).

Discussion

We attempted to provide agronomically relevant conditions and to separate temperature and CO_2 effects from drought stress and nitrogen limitation associated with late season forage production. The methods used eased comparison to the literature (Bidlack et al. 1999; Coblentz et al. 1999; and references therein). Forage quality of field-grown gamagrass during the same season and simultaneously run through the same analyses yielded comparable results (not shown) and were consistent with other reported values (Coblentz et al. 1999).

No attempt was made to segregate stem and leaf, but it is unlikely this substantially influenced the results. Stems in eastern gamagrass arise exclusively from inflorescences which do not typically form the first season, were non-existent except for some at final harvest, and were found only in the lowest temperature plants (Krizek et al. 2004). Forage from the lowest temperature chambers at final harvest was still more digestible (IVDMD) and higher in protein (%N) even though some stem material was present. Nutritive value decreased as the plants developed in the present study but this was less pronounced at higher temperatures (Figures 1 & 2, Table 1). Increased fiber content in later harvests is consistent with both altered plant chemistry and canopy phenology during development, and may have been influenced by clipping and subsequent regrowth. The midrib of cut leaves extends to the distal end of the leaf whereas the midrib of entire intact leaves does not. Hence, the leaf material overall is apparently a bit “coarser” in later harvests. It is surmised that the heavily lignified fibrous midrib in the leaves comprised more of the above ground material in later harvests.

Our values agreed with those from established plots grown in the same year in which no separation between stem and leaf occurred (not shown). Eastern gamagrass stem

material is typically lower in protein and higher in fiber and lignin than leaf material (Bidlack et al. 1999; Coblentz et al. 1999). However, the nutritive value of stem is quite variable. Stem lignin content and IVDMD can approach that of the leaves, although protein content is consistently much lower (Bidlack et al. 1999). Also, eastern gamagrass is a very leafy forage, as compared to other forage crops (Coblentz et al. 1999). Established field grown eastern gamagrass stands typically yield forage which is about 80% leaf (Coblentz et al. 1999). Therefore, a low percentage of stems which exhibit similar digestibility to leaves is characteristic of eastern gamagrass and probably contributed to the similarity between the chamber and field grown forage.

Increased lignin content in response to CO_2 probably did not result from enhanced photosynthesis. When up to 50% of roots were pruned from greenhouse-grown eastern gamagrass plants, yield decreased but lignin content was unchanged (Rhoden et al. 2000). We were unable to detect enhanced photosynthesis with elevated CO_2, and biomass accretion was unchanged (68/57°F), or exhibited slight non-significant enhancements (82/71°F and 95/84°F), (Gitz et al. 2003; Krizek et al. 2004). In the present study the temperature dependent increase in root lignin and %C each amounted to about 5% and the pattern closely resembled that of carbon content (Not shown). This is consistent with alterations in root carbon sequestration from increased partitioning of assimilate into cell wall bound phenolics.

Fiber and lignin increased only a few percent experiment-wide in response to CO_2 consistent with a meta-analysis which found lignin content of leaf litter increasing about 6.5% on average. It was suggested that CO_2 will have little effect on decomposition (Norby et al. 2001).

Warm-season grasses grown in northern climates, produce superior forage to those grown in warmer regions (Salon and Cherney 1998; Coblentz et al. 1999). In the present experiment leaves from low temperature plants appeared to be considerably wider than those of high temperature plants (not quantified). Leaf width has been used as a parameter to classify Texas eastern gamagrass ecotypes. Broad-leaved ecotypes were higher in protein than narrow-leaved blue-green ecotypes (Schliesing and Dahl 1983; Wright et al. 1983). However, the functional relationship of leaf width and forage quality remains unclear (Coblentz et al. 1999). Water availability, soil conditions, maturity, canopy phenology, and harvest interval are responsible for variability in eastern gamagrass forage quality (Brejda et al. 1994, 1996, 1997). Our results suggest that in addition to such factors, first cuttings of gamagrass are more nutritious simply because of lower temperatures during leaf development.

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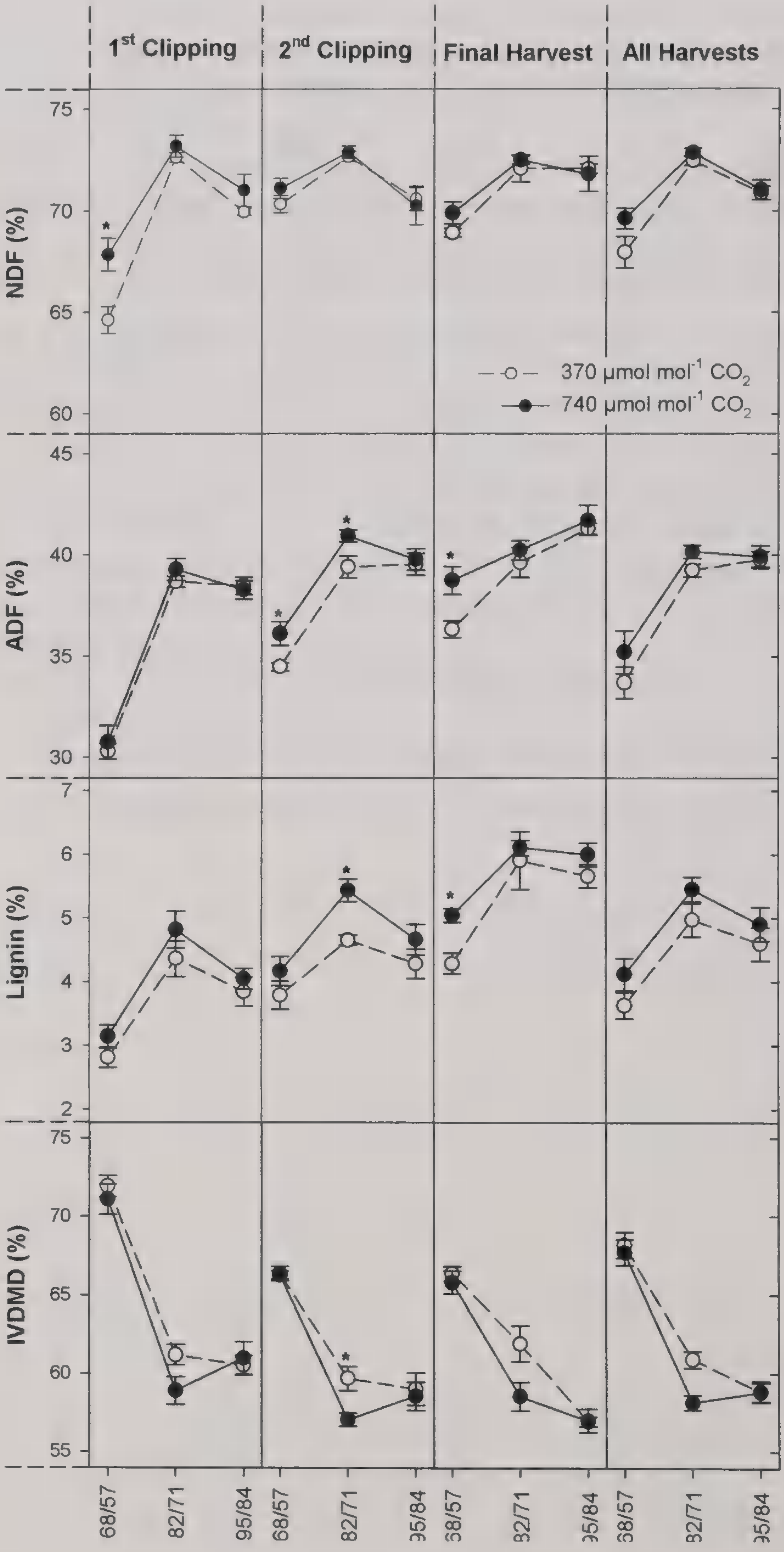
Table 1. ANOVA (PROC GLM; SAS, 1993) of eastern gamagrass leaf data (averages are shown in Figures 1 & 2). Effects of growth under different temperatures (Temp), CO_2 concentrations (CO_2), time of clipping (Harvest), and their interactions on forage quality were modeled. NS indicates probability > 0.1.

	Pr > F						
Source	NDF	ADF	Lignin	IVDMD	C	N	C/N
Temp	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
CO_2	0.007	0.001	<.0001	0.004	NS	NS	NS
Harvest	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Temp x CO_2	0.050	0.094	NS	0.006	NS	0.052	0.057
CO_2 x Harvest	0.068	NS	NS	NS	0.045	NS	NS
Harvest x Temp	<.0001	<.0001	NS	<.0001	<.0001	<.0001	<.0001
Temp x CO2 x Harvest	NS	NS	NS	NS	NS	NS	NS

Figure 1. Neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin and *in vitro* dry matter digestibility (IVDMD) of three clippings taken from eastern gamagrass grown at three temperatures and two CO_2 levels. Open and closed symbols are from 370 and 740 μmol mol^{-1} CO_2 grown plants, respectively. Bars are standard errors. Asterisks denote significant difference between CO_2 treatments (P_t<0.05).



Forage Preference of Pregnant Meat Goats

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Abstract

Goat production has become an attractive alternative livestock enterprise for limited resource farmers in the southern United States. Goats require alternate forages to maximize production and this is critical in that goat production is becoming an important source of income for small-scale farms in the South. Information concerning dietary preference on pregnancy in goats is limited and no data has been found on pregnancy using alternative forages. This study utilized four alternative forages; eastern gamagrass [*Tripsacum dactyloides* (L.) L.], peanut (*Arachis hypogaea* L.), perennial peanut (*Arachis glabrata* Benth.), and fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire] along with bermudagrass [*Cynodon dactylon* (L.) Pers]. Because there is limited information on the performance of meat goats on alternative forages, the objective of this study was to evaluate feed intake, and therefore, the preference of pregnant meat goats on diets of eastern gamagrass (EGG), bermudagrass (BG), peanut (PH), perennial peanut (PPH) and fescue (FC). The experiment consisted of four studies, each lasting 4 weeks for a total of 16 weeks. Each study utilized four pregnant does housed in individual pens. The treatments consisted of four forages and 0.5 lb of concentrate offered once daily with water and mineral blocks provided ad libitum. Feed intake and refusals were monitored daily. In Study 1 the preference was PPH > EGG > PH > BG, with an average weekly intake of 1.69 ± 0.07 lb for PPH. In Study 2 PPH was replaced with FC. The results for Study 2 was PH > EGG > BG > FC with an average weekly intake of 1.50 ± 0.06 lb of PH. In Study 3, PPH was added to the forages in the previous study to see if there would be an increase in the consumption of those forages. The does' preference in this study was BG+PPH > PH+PPH > EGG+PPH > FC+PPH, with an average weekly intake of 1.13 ± 0.04 lb for BG+PPH. In Study 4, liquid molasses was added to EGG and FC. The pregnant does preferred EGG+M > EGG > FC+M > FC with the average weekly intake of 0.72 ± 0.03 lb for EGG+M. The overall hierarchy of preference was PPH>PH>EGG>FC, in addition, the combination of PPH with BG, EGG and FC increased intake, while the addition of molasses did not significantly increase the intake of EGG or FC.

Key words: Bermudagrass, eastern gamagrass, forage preferences, goats

Introduction

Goats generally prefer to alternate between different feeds. They utilize a much wider variation of plant types and select the materials with the highest nutrient concentration (Duncan and Young 2002; Getz et al. 2005). When given the opportunity, animals tend to select feeds according to their taste and preferences, which do not necessarily correspond to the nutritional value of the feeds (Morand-Fedr 2003). It has been proposed that goats' preference originate from the interrelationship between a feed's taste and its post-ingestive

feedback, which is determined by a goat's physiological state and food chemical composition (Provenza 1999). Because of this wide range of choices, forages such as peanut hay, perennial peanut hay, eastern gamagrass, and tall fescue can be suitable alternatives to bermudagrass which is the primary forage used in the beef cattle industry in the southeast US.

Bermudagrass is a warm-season perennial that has been traditionally used as hay during the winter months. Many producers are searching for alternative forages than can equal or exceed the nutritive value of bermudagrass. Eastern gamagrass is a robust, perennial, warm-season, bunchgrass that is native to the U.S. Eastern gamagrass is also fast growing, drought tolerant and grows where fertility is low. This grass was once abundant in hundreds of thousands of acres but is now common only in areas protected from grazing. It has been found to have moderate nutritional value, and is highly palatable to livestock (Bailey et al. 1998). Peanut hay consists of the vines and leaves of the peanut plant. It can be a high quality feed when properly cured and baled and is very palatable to beef cattle. Peanut hay should be wrapped or stored indoors because excessive dry matter and nutrient loss will occur with unprotected bales. Perennial peanut is a primitive peanut that produces very few seeds in contrast to the common peanut. It is a warm-season tropical legume native to South America. Its potential uses include hay and other dehydrated products, pasture, creep grazing, and silage. Perennial peanut fills a unique niche because there are no other perennial warm-season legumes that rival its forage quality, persistence, and broad spectrum of uses (French et al. 2000). It has been called "Florida's alfalfa" because it fits so closely the quality characteristics of alfalfa as an animal feed.

Tall fescue (FC) is a cool-season, perennial bunchgrass that has enjoyed much popularity over the past 50 years. Most of the FC grown in the southeastern US is Kentucky 31 (KY-31). Fescue has been popular as a pasture grass because of its wide variety of management regimes. Tall fescue has a high quality of dry matter, crude protein, cell wall content, and minerals and it should give good animal performance (Pinkerton et al. 2001).

Goats were given free access to alfalfa and PPH, and PPH was preferred over alfalfa during a 5-month trial period (Terill et al. 2000). In every study conducted to date, when given the choice, horses, cattle, sheep and goats all consumed PPH before any other grasses (Crosswinds 2004). Research has shown that there are pregnancy-related problems associated with the consumption of FC. These include lower feed intake, lower milk production, reduced reproductive performance, more time spent in shade and water and necrosis of hooves and tails, commonly known as fescue foot (Bates 1997; Schmidt and Osborn 1993). Broderick and Radloff (2004) stated that dry matter intake increased with the first increment of molasses supplement; however, production declined after maximal intake indicating that the sugar was fed in excess.

Little is known about how well goats would perform when offered these forages. Therefore, the goal of this study was to determine diet preference of meat goats fed alternative forages and assess the amount consumed. The specific objectives were:

1. To determine the hierarchy of preference of meat goats when given a choice of PPH, PH, BG, and EGG.
2. To determine the preference when FC replaced PPH while the other forages remained the same.
3. To determine if PPH had a synergistic effect on the intake of other forages.

4. To determine if molasses would increase the intake of the two least preferred forages, EGG and FC.

Materials and Methods

There were five different forages utilized during this research: BG, EGG, PH, PPH, and FC. Each forage along with the concentrate (Nutrena Sweet Stuff ™) was analyzed by Auburn University Forage and Feed Analysis Laboratory (Table 1). The experiment consisted of four studies each lasting 4 wks. Each study utilized four pregnant does that were at least 3 months in gestation. The goats were housed in individual pens. The treatments consisted of the four forages from which they selected their daily consumption. The forages were supplemented with 0.5 lb of concentrate daily and the studies were conducted for 16 weeks. Animals were fed once daily and water and mineral blocks were provided ad libitum. Feed intake and refusals were monitored daily. The chemical compositions of the different forages are in Table 1. In Study 1, the forages offered were BG, EGG, PH, and PPH while in Study 2, PPH was removed and replaced with FC, with all other forages remaining the same. Since it was established from the previous study that PPH was the overwhelming favorite forage for the goats, in study 3, PPH was added (50:50) to the four forages from Study 2 to ascertain if there would be an increase in the consumption of these forages. The diets, therefore, consisted of PPH+BG, PPH+EGG, PPH+FC and PPH+PH. In Study 4, molasses was added to the least preferred forages, EGG and FC (EGG+M and FC+M) in order to observe any increase in intake. All four studies had four replications in a completely randomized designed (CRD), and the General Linear Model (GLM) procedure of SAS (2001) was used to analyze the data. Where AOV showed significance, means were separated using Tukey's studentized range test (Steele and Torrie 1980).

Results

Study 1 The order of preference in this study was PPH>EGG>PH>BG for pregnant does, with PPH preferred significantly ($P<0.05$) over the other forages with 1.69 lbs average daily intake (Table 2). In addition, the average daily intake of PPH was more than twice that of the other forages offered with BG having the lowest consumption (0.50 lbs). *Study 2* In this study, PPH was replaced with FC and results showed that the preference was PH>EGG>BG>FC (Table 3). The intake of PH (1.50 lbs) amounted to three times that of FC (0.44 lbs). *Study 3* Perennial peanut hay was added to each of the other forages to observe if there would be an increase in intake. The order of preference was PPH+BG>PPH+PH>PPH+EGG>PPH+FC (Table 4). The combination of PPH increased the intake of BG, EGG and FC compared to the amounts of these forages consumed in studies 1 and 2. However, the combination of PPH+PH was lower than the intake reported in study 2 for PH. *Study 4* Based on the previous studies, EGG and FC were the bottom two forages in terms of preference. When molasses was added to these two forages, the goats showed a preference for EGG+M>EGG>FC+M>FC (Table 5). Although there were no significant differences, the intake of fescue was higher than in the previous studies.

Discussion

The results of Study 1 showed that PPH was overwhelmingly preferred by the pregnant does when compared to the other forages. This result seem to be in agreement with the findings of Terill et al. (2000), Crosswinds (2004) and Getz et al. (2005) who all concluded

that when given a choice, most ruminants selected PPH over grasses. When PPH was replaced by FC in Study 2, intake of PH was three times more than FC; however, when PPH was combined with FC in Study 3 there was an increase of 0.43 lbs compared to Study 2 where the average weekly intake was 0.44 lbs. The intake of EGG also increased when combined with PPH from 0.80 lbs to 1.03 lbs in Study 3. This is a strong indication that there seem to be a synergistic effect between PPH and these other forages. These results support the findings of Early and Provenza (1998) who reported that feed intake will increase when a variety of feed is offered to livestock in confinement.

The addition of molasses to EGG and FC in Study 4 did not significantly increase intake over EGG or FC alone despite the reports of Pate et al. (1990) who found increases. However, when EGG and FC were offered in combination with PPH or molasses, there was increased consumption rate over the previous studies. There were no gestation complications because of feeding fescue to these pregnant does as has been reported in the literature.

Conclusion

When given a choice, meat goats will consume high quality forages before they eat low quality material. Perennial peanut hay is either comparable or better in nutrient composition than good quality hay. Molasses will improve it value as a supplement when offered with low-quality forage.

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Table 1. Nutrient composition of the five forages used in this experiment

Forages[a]	TDN[b]	CP	NDF	ADF
	------% of dry matter------			
BG	49.7	12.3	73	35
EGG	50.3	4.9	72	41
PH	48.3	7.9	61	50
PPH	52.8	14.2	51	43
FC	47.9	12.5	76	42

[a]BG=bermudagrass hay; EGG=eastern gamagrass hay; PH=peanut hay; PPH=perennial peanut hay; FC= fescue hay

[b]TDN=total digestible nutrients; CP=crude protein; NDF=neutral detergent fiber; ADF=acid detergent fiber

Table 2. Average weekly intake of pregnant does in Studies 1-4.

Forage[a]	Average weekly intake (lb)
	Study 1
PPH	1.69 ± 0.07
EGG	0.66 ± 0.08
PH	0.53 ± 0.05
BG	0.49 ± 0.03
	Study 2
PH	1.50 ± 0.06
EGG	0.80 ± 0.02
BG	0.63 ± 0.04
FC	0.44 ± 0.06
	Study 3
BG+PPH	1.13 ± 0.04
PH+PPH	1.12 ± 0.06
EGG+PPH	1.03 ± 0.05
FC+PPH	0.87 ± 0.04
	Study 4
EGG+M	0.97 ± 0.04
EGG	0.94 ± 0.03
FC+M	0.92 ± 0.03
FC	0.88 ± 0.03

[a]BG=bermudagrass hay; EGG=eastern gamagrass hay; PH=peanut hay; PPH=perennial peanut hay; FC= fescue hay; M=molasses

Influence of Alternative Forages on Reproductive and Productive Characteristics of Meat Goats

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Abstract

Goats are sources of meat, milk and fiber. They reach puberty at 5 months, have a gestation period of 150 days and produce twins. Forages provide energy for maintenance, growth and reproduction. Three grasses; bermudagrass (BG) (*Cynodon dactylon (L.) Pers.*), eastern gamagrass (EGG; (*Tripsacum dactyloides* (L.) L.)) and endophyte infected tall fescue (EIF; *Lolium arundinareum* (Schreb.) S.J. Darbyshire) were used to evaluate the effects of certain reproductive and productive characteristics of meat goats. Thirty Boer X Spanish female goats (2-4 yrs old) were assigned to one of three forages (hay) throughout the study. Estrus was synchronized using Prostaglandin F2α and does were naturally bred. Ultrasounds were performed at day 60 and 90 to confirm pregnancies. At 60 days, there were 50 (EGG), 30 (EIF) and 20 (BG) percent conception rates. At day 90 conception rate was 100% for all treatment groups. Mean total kid birth weight/doe was highest ($P<0.05$) for BG (16.2 $\pm$ 1.3 lb), followed by EGG (14.7 $\pm$ 0.7 lb), with EIF significantly ($P<0.05$) lower (12.2 $\pm$ 1.3 lb) than BG. Although not significantly different, average daily (ADG) gain was highest for kids fed EGG (8.4 $\pm$ 1.0 oz). This was followed by EIF (8.0 $\pm$ 0.6 oz), with BG having the lowest (7.1 $\pm$ 0.9 oz) ADG. Mortality rates were 20% (BG), followed by 21.05% (EGG) and EIF with 36.36%. Weaning weights for kids at 4 months of age were highest for EGG (39.7 $\pm$ 6.2 lb) followed by BG (38.4 $\pm$ 2.3 lb) with EIF having the lowest ($P<0.05$) at (32.0 $\pm$ 6.2 lb). The results show that conception rates of does as well as ADG and mortality rates of kids were not significantly different. However, EIF contributed to the lowered birth and weaning weights of kids.

Key words: Bermudagrass, Eastern gamagrass, fescue, forage, goat growth

Introduction

The meat goat industry in the southeast is growing rapidly (McGowan 1995). The increasing economic importance of meat goat production in the U. S. can be attributed both to a strong demand for goat meat and to an interest in ecologically sound forms of vegetation control (Coffey 2002).

In animals kept solely for meat production, reproductive efficiency is of critical importance to the viability of the enterprise because reproduction is the main purpose. Meat production is about growth, and growth of an animal to weaning often sets the platform upon which post-weaning growth is built (Walkden-Brown 2001). Goats are among the most prolific ruminants found on the farm. They reach puberty at 4-7 months of age depending on the breed and the level of nutrition received. Breeding size for most breeds of goat is 84 to 88 lb that is reached at 9-10 months of age. Goats often give birth to one or two kids, but it is possible for them to produce three or four. It is more desirable for a doe to give birth to twins. The gestation period of the goat range from 147 to 155 days (Walkden-Brown 2001).

Forages make up the principal portion of the goat's diet and may be from pasture, hay, silage, or crop residues. Forage supplies energy, protein, minerals, and vitamins and is used in the animal's growth and development (Gillespie 1998). Bermudagrass is found throughout the tropical and subtropical parts of the world and is drought resistant (Higgins 1998). It will grow on any moderately well drained soil provided it has an adequate supply of moisture and nutrients. Bermuda grass is used as the standard for measuring the quality of other grasses (Scarbrough et al. 2001). Eastern gamagrass is a warm-season, perennial bunch grass found growing naturally from the Northeastern and North Central United States and south into Mexico, Central America, and the Caribbean, and into Bolivia and Paraguay in South America. It has agronomic and quality characteristics that make it excellent forage for grazing or mechanical harvest. Eastern gamagrass grain also has an excellent nutritional value comparable to corn with a high level of protein (27%) and a good amino acid balance. Eastern gamagrass grain has potential as a protein and energy supplement for ruminants because of its relatively high protein and energy content (Bailey and Simms 1998).

Tall fescue is the most important cool-season grass in the United States, providing the primary ground cover on some 35 million acres. It is a versatile perennial used for livestock feed, various turf purposes, and erosion control. The advantages of fescue are that it is tolerant of shade, drought, and flood; it is resistant to many diseases, insects and heavy grazing. It is known to out-compete other grass species (Roberts 2000). The disadvantages are that it causes dystocia, fescue foot, aglactia, reduced weight gain, fat necrosis and retained placentas. Unfortunately, fescue contains a toxic fungus that lives within the plant called endophyte (*Neotyphodium coenophialum*). The endophyte produces metabolites that are toxic to grazing animals (Roberts 2000). Species or cultivars of a grass or legume, which has been developed for a specific agronomic purpose, have been found to contain compounds, which in some way depress animal performance. Such problems are often localized in their occurrence but may cause serious economic loss in a given area or at certain times of the year. This study was designed to determine the effects of alternative forages; Bermuda grass, eastern gamagrass, and endophyte infected fescue on the reproductive and productive characteristics of meat goats.

Materials and Methods

The study was conducted at the Tuskegee University Caprine Research Unit - George Washington Carver Agricultural Experiment Station, Tuskegee University, Alabama from August 2005 through May 2006. Thirty Boer-Spanish cross female goats between the ages of 2 to 4-years old were used for the study. Goats were randomly assigned to one of three treatment groups: (1) endophyte-infected tall fescue hay (Kentucky-31) (EIF), (2) eastern gamagrass hay (EGG) or (3) bermudagrass hay (BG) (n=10). All animals had free access to water and salt/mineral blocks. The design for the study was a complete randomized design. Does were given a 70:30 hay/concentrate (Nutrena Sweet Stuff ™) ration based on 5 % of their body weight. For each doe, estrus was synchronized with 2 intramuscular injections of Prostaglandin F2α (Lutylase) (Sterile Solution) on day 1 and day 11. On day 11, one of three Boer-Spanish bucks was randomly assigned to one of the treatment groups of does. Bucks were removed after 60 days of cohabitation. Ultrasounds were performed by rectal ultrasonography on days 61 and 90-post breeding. Within 24 hours of birth, kids were weighed, sexed, identified, and navels were dipped in iodine solution. Weights of the kids

were taken once a week until one month post partum to determine average daily gain per treatment group. Kids were weighed weekly until weaning at 4 months of age.

Results and Discussion

The reproductive and productive characteristics evaluated in this study were conception rates, birthweights, average daily gain, mortality rate and weaning weights. These are some of the factors that are of concern to farmers in the Blackbelt Region of Alabama. There was no difference in the influence that the three forages had on breeding and conception rate (Table 1). Therefore, farmers can use any of these forages without any loss in conception rate.

Kids from does in the BG group had the highest mean birthweight per doe (Table 2). Kids from the does in the EGG group had mean birth weights per doe that was not significantly different from either BG or EIF. Kids from does in the EIF group had the lowest mean birthweight per doe and was significantly lower than BG. This is similar to results obtained by Schmidt et al. (1993) and Conover et al. (2003) who reported that feeding does endophyte infected fescue resulted in low birthweight. As with birth weights, similar results were obtained with the average daily gain (ADG). Figure 1 shows the ADG from birth to one month postpartum and although there was no significant difference, EGG had the highest ADG followed by EIF while BG produced the lowest ADG. The major differences were seen between EGG and BG and have implications among the limited and small-scale goat producers in Alabama as this indicate additional income from feeding EGG.

Mortality rate was not significantly different among the three forages (Figure 2). EIF had the highest mortality rate of 36.4% followed by EGG at 21.0%. BG had the lowest mortality rate at 20%. Coupled with mortality rates was the weaning weights taken at 4 months. These weights were highest for EGG ($P<0.05$) followed by BG and lowest for EIF (Table 2). This data show that kids from the EIF group produced the lowest weights. The weaning weights were significantly different between kids from EGG and EIF treatments. The reduction of weight attributed to EIF was also reported in research done by Burke et al. (2005). Again, this has implications for goat producers, as it is important that they have hay that will maximize their productivity.

This study has far reaching implications in the Alabama's goat industry. Eastern gamagrass and EIF compared well to BG in their influence on reproductive and productive performance. Eastern gamagrass can be considered an alternative forage for goats during breeding and gestation and post parturition. However, since the does on EIF treatment produced kids with low birth weights and with the lowest average daily gain as well as weaning weights, EIF does not exhibit qualities as good forage for reproduction and production in meat goats unless the does are removed from the hay during the last trimester of gestation.

Acknowledgment

I would like to thank my Graduate Advisors; Drs. E. G. Rhoden and J. R. Bartlett for their patience, determination and wisdom that helped me carry out the research in a productive and positive manner. I would also like to thank A. White, N. Harris- French, A. Pokoo-Aikins, O. Aribisala, V. Khan, Dr. C. Bonsi and Dr. K. Copedge (DVM), for their dedication and appreciated assistance.

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Table 1. Conception rates (%) of does on days 60 and 90 fed eastern gamagrass, endophyte infected fescue and bermudagrass

	EGG[1]	EIF	BG
Day	---	%	---
60	50	30	20
90	100	100	100

[1]EGG, eastern gamagrass; EIF, endophyte infected fescue; BG, bermudagrass,

Table 2. Mean birth and weaning weights of kids of does fed eastern gamagrass, endophyte infected fescue and bermudagrass

Parameters	EGG[1]	EIF	BG
Birth weight (lb)	14.7[a]	12.1[b]	16.2[a]
Weaning weight (lb)	39.7[ab]	32.0[b]	38.5[a]

[1]EGG, eastern gamagrass; EIF, endophyte infected fescue; BG, bermudagrass,
[a,b] Means with different superscripts in the same row differ significantly (P<0.05)

Figure 1. Average daily gain of kids (from birth to 28d. postpartum) for bermudagrass (BG), eastern gamagrass (EGG) and endophyte infected fescue (EIF).

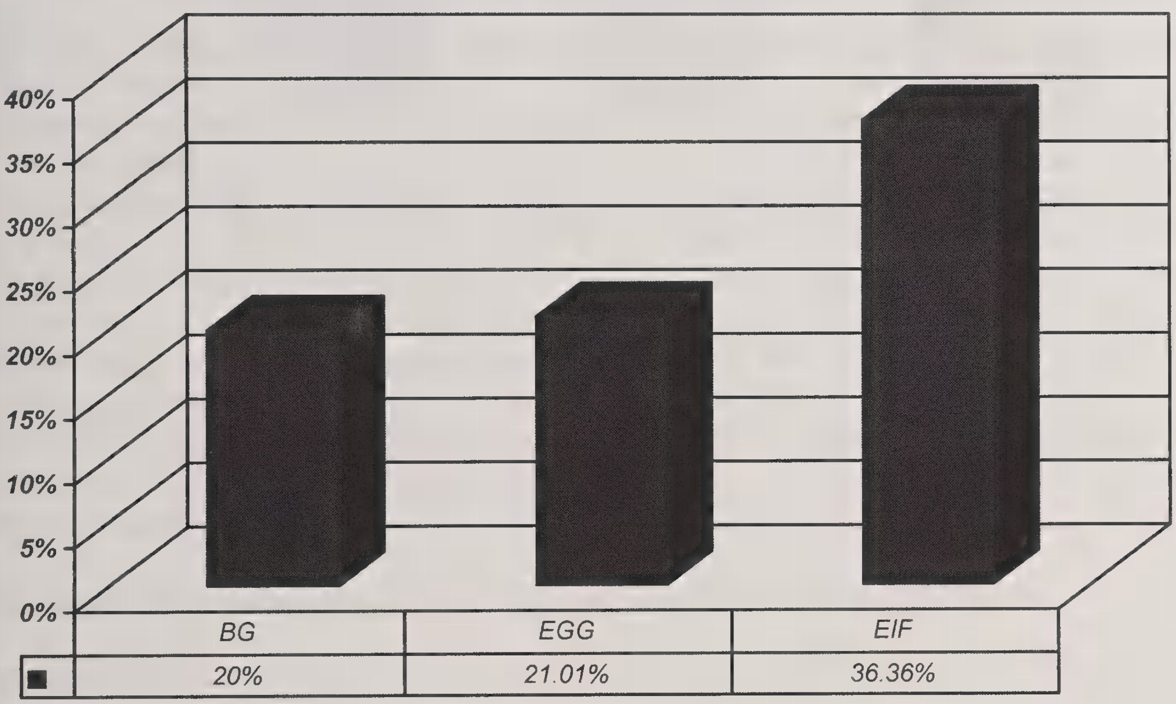
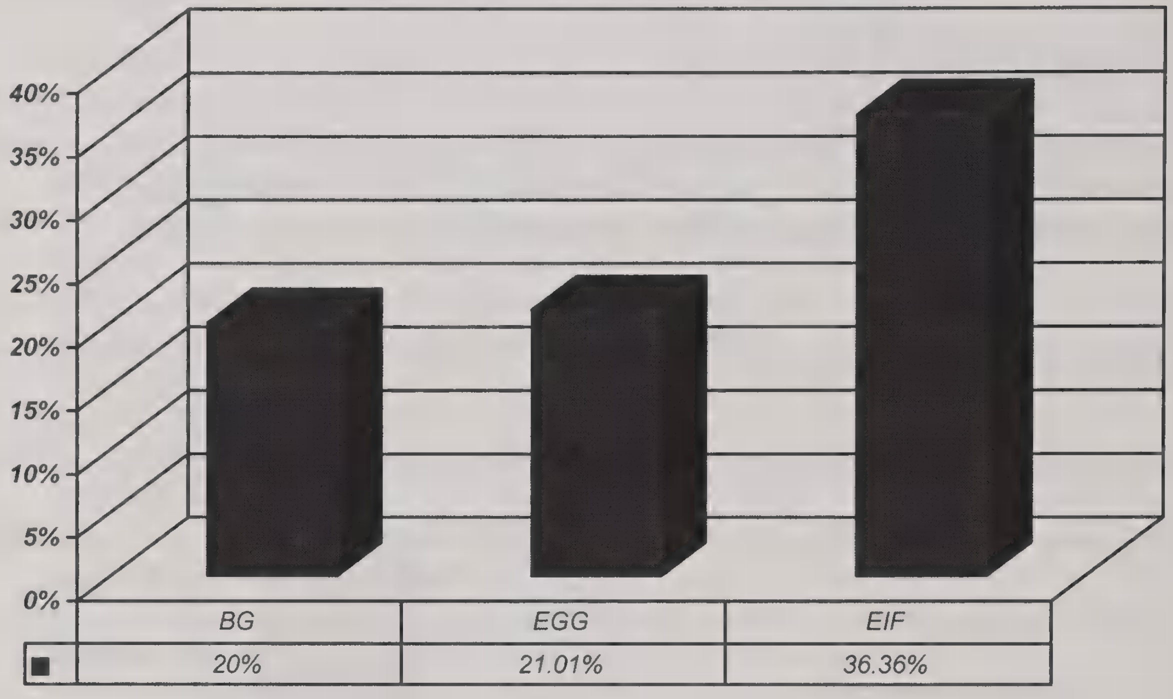


Figure 2. Mortality rates (%) of kids from bermudagrass (BG), eastern gamagrass (EGG) and endophyte infected fescue (EIF).



Forage Preference of Spanish Wethers

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Abstract

Forage is an important aspect of raising small ruminants. Bermudagrass [*Cynodon dactylon* (L.) Pers.] is used as a standard for measuring the quality of other grasses in the southeastern United States while peanut hay (*Arachis hypogaea* L.) is underutilized. Perennial peanut (*Arachis glabrata* Benth.) a leguminous forage that is an excellent substitute for alfalfa (*Medicago sativa* L.), fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire.], a cool-season grass and eastern gamagrass [*Tripsacum dactyloides* (L.) L.], a native summer bunch-grass, are underutilized in goat research. Goats are selective in their browsing habits and exposure to a wide range of feed choices is important. Therefore, the objective of this study was to evaluate the forage preferences of Spanish wethers fed alternative forages. Six wethers were individually penned and fed combinations of bermudagrass (BG), peanut hay (PH), perennial peanut hay (PPH) along with fescue (FC) and eastern gamagrass (EGG) with and without molasses over a sixteen-week period. These forages were supplemented with 0.5 lb of concentrate/ animal daily. Water and mineral blocks were provided ad-libitum while feed intake and refusals were monitored daily. Results indicated that when Spanish wethers were given a choice between BG, EGG, PH, and PPH their diets consisted of about 56% PPH. When the diet choices were PH, BG, EGG and FC, PH comprised 49% of the Spanish wethers' diets. When PPH was added to the diets of the other forages (50:50) consumption of the forages ranged from 16% (PPH: FC) to 30% (PPH: EGG). Incorporating molasses into FC and EGG resulted in higher consumption of both forages. Perennial peanut hay was the preferred choice of forage and incorporating PPH or molasses increased consumption of forages by Spanish wethers.

Key words: Bermudagrass, eastern gamagrass, peanut hay, tall fescue

Introduction

Goats are the smallest domesticated ruminants and they have been utilized by humans earlier and longer than either cattle or sheep (Extension Goat Handbook 1992). Goats are selective in their feeding habits and prefer to select from a variety of grasses, shrub, plants, and leaves. They are good converters of grasses or plant products into meat and prefer grasses, shrubs or feed with very high nutritional value. When provided with a variety of feed options, they prefer feeds that are palatable even if it has poor nutritional value (Getz et al. 2005). In order to maximize production and at the same time be cost-effective, it is important to have readily available, less expensive good quality feeds or grasses. If this can be achieved, production could increase at a lower cost and there could be a supply of meat to consumers at a lower cost which would make goat meat (chevon) affordable and in so doing increase the demand for chevon.

Peanut hay consists of the vines and leaves of the peanut plant that is usually discarded during peanut production. This alternative forage is a high quality feed when

properly processed and stored. It is routinely fed to cattle and is a readily available alternative feed source during the fall/winter months. Peanut hay should be properly processed and stored to prevent nutrient loss, which occurs when left unprocessed and uncovered (Rankins 2004).

Perennial peanut is a primitive peanut. When compared to the cultivated peanut, perennial peanut produces fewer seeds. It is a tropical perennial legume and is found growing the southeastern USA. It was introduced from South America and is used to improve the quality of some silage as well as in creep grazing, pasture, hay or incorporated with other forages to improve nutrition. Perennial peanut is commonly known as "Florida's alfalfa" and routinely substituted for alfalfa (Crosswinds Farm 2004).

Tall fescue is a perennial cool-season. The variety mostly grown in the southeastern U.S. is Kentucky 31 (KY-31). Fescue is a widely known pasture grass because of its variety of management uses. It does well on poor soils, is able to withstand long periods of grazing with good winter growth. Tall fescue has a high quality dry matter and good crude protein content but is often associated with an endophyte fungus causing growth and reproductive problems (Hill *et al.* 1994).

Bermudagrass is a warm-season perennial grass that is widely stored as hay for use during the winter months. It has high nutritional value that has made it a popular hay in the beef cattle industry in the southeast U.S. Producers are constantly looking for alternative forages with higher or equal nutritive value as Bermuda grass that are less expensive.

Eastern gamagrass is a robust perennial warm-season bunch grass that is native to the U.S. Eastern gamagrass is fast growing, drought tolerant and grows on low fertility soils. It has moderate nutritive value and is highly palatable to livestock. Very little is known on how well goats perform when fed these four alternative forages. Therefore, the overall objective of this study was to determine forage preferences of Spanish wethers (meat goats) fed alternative forages and assess the amount consumed. The specific objectives for each study were (1) to determine the preference among PPH, PH, BG and EGG; (2) to determine the performance of Spanish wethers on FC, PH, BG and EGG; (3) to determine if peanut hay will increase the intake of other alternative forages and (4) to determine if molasses will increase the intake of the most and least preferred alternative grasses (EGG and FC).

Materials and Methods

Five different types of hay were used during this research, bermudagrass (BG), eastern gamagrass (EGG), peanut (PH), perennial peanut (PPH) and fescue (FC). All the hay used was analyzed for nutrient composition (Table 1). The research consisted of four studies. Each utilized six Spanish wethers that were 9 months old. They were individually housed in pens and provided with water and mineral blocks ad libitum. The research with the six wethers was conducted for a total of sixteen weeks (four 4-week studies) and treatments consisted of a combination of four forages, which were provided as choice and supplemented with 0.5 lb of concentrate (Nutrena Sweet Stuff ™) daily for the first 8 weeks and 0.75 lb after 8 weeks. The goats were fed once daily (5% body weight) and each feeding met NRC (define NRC) requirements. Feed intake and refusals were monitored daily and body weights were recorded weekly. In study 1 (Weeks 1-4) the forages offered were BG, EGG, PH and PPH while in study 2 (Weeks 4-8) the wethers were offered BG, EGG, FC and PH. In study 3 (Weeks 9-12) PPH was added to the forages offered in study 2 and for study 4 (Weeks 13-16) molasses was added to the most and least preferred alternative grasses (EGG and FC).

Results and Discussion

The results that are reported are based on the feeding of the forages for four weeks. In study 1 the feed preference was based on the quantity of forage consumed. Spanish wethers preferred the forages in the following order; PPH (55.8%), EGG (21.1%), PH (11.5%) and BG (11.1%) (Fig. 1). This clearly indicated a preference for PPH, as the wethers would clearly seek out the container with the PPH prior to going to any other choice of hay.

Study Two

In order to explore the behavior of the Spanish wethers, the most preferred hay in study one (PPH) was replaced with fescue. The intention was to determine if PPH were removed from their choice of forages would it cause a decrease in consumption and subsequently loss of weight. The data show (Fig 2) that their hay preference was radically changed. Peanut hay that was not highly utilized in the first study actually replaced PPH as the first choice (49.3%) of the goats. The forage that was the second choice in Study 1 (EEG) was being consumed at one half the rate of PH (24.7%) while BG was being consumed at 15.4% and FC comprised only 10.6% of the wethers' diets. It was expected that EGG would have replaced PPH as the preferred forage, but it can be speculated that one legume may have substituted for another. In looking at the quality of PH it was not superior to EGG but the goats preferred it. FC being the least preferred hay among the forages being studied has been noted in other studies conducted at Tuskegee University. Markley et al. (2006), working with does that were going through pregnancy found deleterious effects from FC. Harris-French et al. (2006) have shown that pregnant does routinely selected FC the least of the different forages fed. Aribisala et al. (2006) noted that whenever the choice was between EGG, BG and FC, FC was the least consumed and suggested that it might also be associated with reduced weight gains.

Study Three

When PPH was added to the other forages it was hoped that forage intake would be increased. There was a noted increase in the amount of feed that was consumed by the weathers. In examining the data (Fig. 3), it was noticed that the preference of the goats was also modified and the combination of EEG/PPH (29.8%) was the most liked forage followed by PH/PPH (26.5%), BG/PPH (25.4%) and FC/PPH (18.3%). When the goats were fed in the mornings they routinely went through the forage and selected the PPH that was mixed then when that was finished they consumed the other forages. Therefore, the consumption pattern of the different forages by the goats in study 1 and 3 was not different. Again, when the goats were satisfied with the amount of PPH they consumed, they ate EGG, BG and PH in the same sequence.

Study Four

In order to influence the amount of forage consumed, molasses was added to the most (EGG) and the least (FC) preferred grasses. In so doing, it was observed that molasses did not influence the amount of FC consumed. Figure 4 shows the preference of the two forages as influenced by molasses and it was noted that EGG/molasses showed the highest percentage consumption of 26.6% followed by EGG alone (25.3%). On the other hand, when

goats were exposed to all four feeds, FC/molasses comprised 24.1% of their diet and FC by itself only 24.1%.

Conclusion

The deleterious effects of tall fescue are often reported and its association with an endophyte fungus causes toxicity in animals. Although the toxic effect of fescue is a factor that reduces feed intake, weight gain and animal performance we can mask this effect by supplying a variety of forages. Though there was reduced intake of fescue in this study, the overall total intake by wethers was not severely impacted by the presence of fescue in the diet. PPH was the preferred hay and whenever included in the array of forages fed, improved intake. It was noted that removing one legume (PPH) from the mix resulted in another legume (PH) being the preferred hay. It was also observed that whenever the other forages were mixed with PPH, EGG was the preferred choice. Furthermore, when eastern gamagrass and fescue were mixed with molasses, EGG was still the preferred forage.

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Table 1. Nutritive values of hays.

Forage	TDN[1]	Crude Protein	NDF	ADF
	---------------------------------% of dry matter--------------------------------			
PPH[1]	50.0	17.1	55.6	34.0
PH	48.0	10.8	48.0	43.0
BG	50.3	12.4	72.0	36.3
EGG	52.7	12.6	68.8	34.0
FC	45.4	11.8	72.0	39.8

[1] PPH, perennial peanut; PH, peanut hay; BG, bermudagrass; EGG, eastern gamagrass; FC, tall fescue; TDN, total digestible nutrients; NDF, neutral detergent fiber; ADF, acid detergent fiber.

Figure 1. Food preference experiment (Study 1) on six wethers fed bermudagrass, eastern gamagrass, peanut hay, and perennial peanut hay.

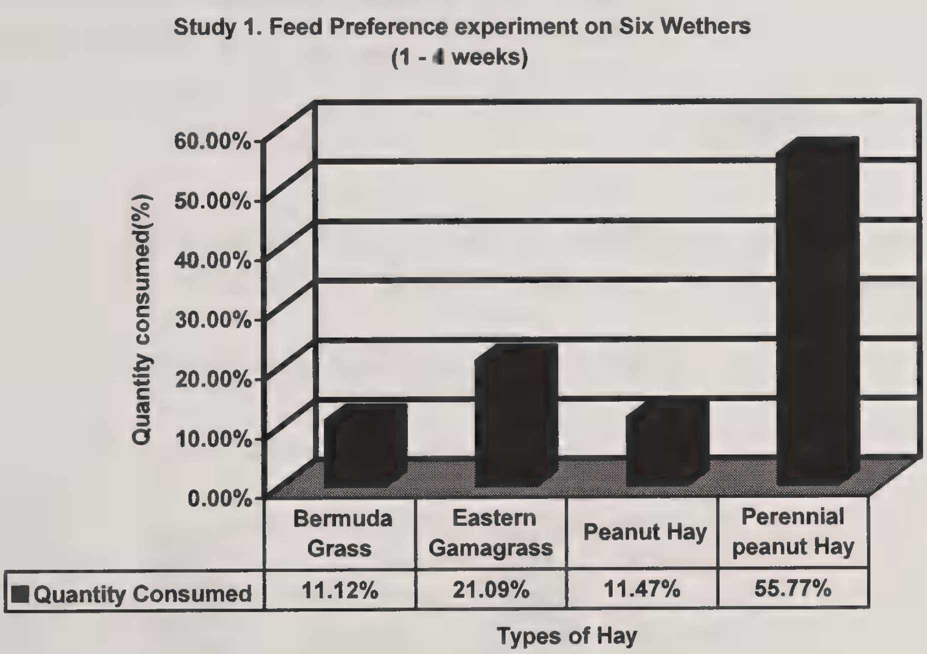
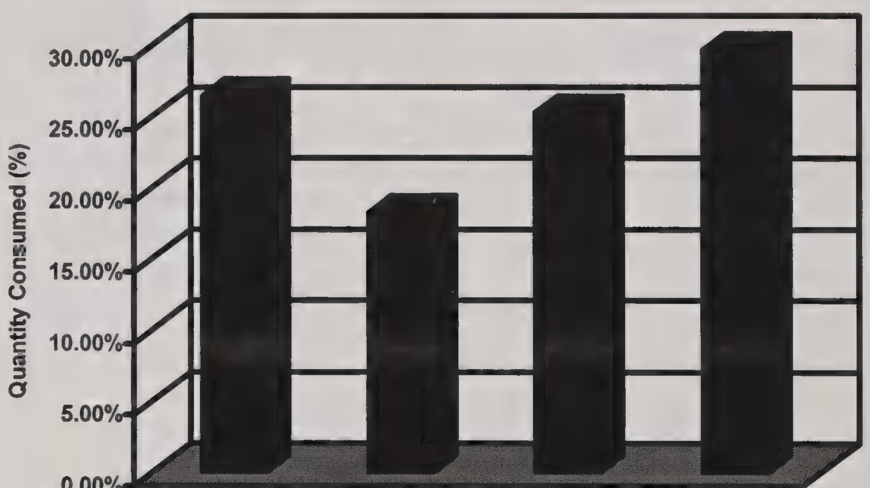


Figure 2. Food preference experiment (Study 2) on six wethers fed bermudagrass, eastern gamagrass, peanut hay, and fescue.

	Bermuda Grass	Eastern Gamagrass	Peanut Hay	Fescue
■ Quantity Consumed	15.44%	24.72%	49.25%	10.59%

Types of Hays

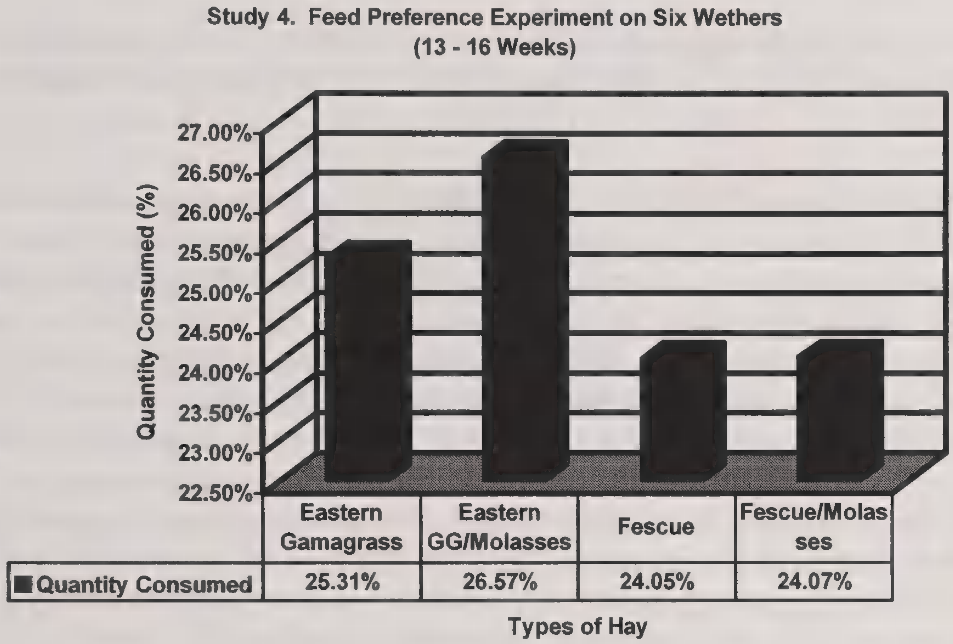
Figure 3. Food preference experiment (Study 3) on six wethers fed bermudagrass, eastern gamagrass, peanut hay, and fescue mixed with perennial peanut hay (50/50).



	Perennial PH/Peanut Hay	Fescue/Perennial P Hay	Bermuda G/Perennial P	Eastern GG/Perennial
■ Quantity Consumed	26.54%	18.33%	25.35%	29.77%

Types of Hay

Figure 4. Food preference experiment (Study 4) on six wethers fed eastern gamagrass and fescue with molasses added.



Response of Meat Goats to Eastern Gamagrass Diets

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Abstract

Eastern gamagrass [*Tripsacum dactyloides (L.) L.*] is a warm-season bunch-type forage grass with moderate crude protein content. Today, goat production is an important source of income to small-scale farms in the southeast. Therefore, the objective of this study was to evaluate weight gain, feed intake, carcass weight and the weight of specialty cuts of meat goats fed eastern gamagrass (EGG). The study utilized 18 Boer cross goats (4-5 months old) individually penned and fed one of three dietary treatments: 80:20 (A); 70:30 (B); and 60:40 (C) (EGG: concentrate) for 12 weeks. Feed intake and refusals were monitored daily and feed offered was adjusted on a weekly basis. Body weight was recorded weekly. Animals were slaughtered at 12 weeks and hot and cold carcass (24 hrs after slaughter) weights recorded. Liver, heart, lungs, viscera (intestine), kidney, pelt, testicles, head and feet were weighed. Specialty cuts (shoulder, ribs, loin, leg and neck) weighed. Animals fed diet A had a daily intake of 2.2 lb, which was significantly lower ($p<0.05$) than B (2.6 lb/day) and C (2.4 lb/day). Animals fed diet C had the highest average daily (ADG) gain (3.3 oz/day) while the animals on diet B had the lowest (2.3 oz/day). Animals in diet A had the greatest leg circumference (1.3 in) while animals in diet C had the lowest (1.2 in). Loin eye area was not significantly difference among the diets. Animals in diet B had the longest carcasses (24.9 in) and animals fed diet A had the shortest carcasses (23.6 in). There was no significance difference in specialty cuts among the diets. Eastern Gamagrass shows significant potential as high quality alternative forage for goats.

Key words: Carcass weights, Eastern gamagrass, goats

Introduction

The world's goat population of 720 million is 48% higher than in 1985, with the US having about 3 million, mostly in the south (Ensminger and Parker 2002). Meat goat production is receiving more attention in the US due to the high returns that can be realized from this enterprise. Eastern gamagrass is a warm-season perennial tall bunch grass native to the southeast. It is high in energy, digestible (TDN 57.45%) with moderate crude protein (14%) and is excellent forage for livestock (Rhoden *et al.* 2002). The earlier settlers have always regarded EGG as a high-quality forage crop, but native stands were destroyed to produce grain crops or overgrazed by livestock. Yields greater than 6.5 tons dry matter/acre have been recorded in Missouri (Roberts and Kallenbach 1999). Eastern gamagrass has excellent potential for hay production and can be harvested more than once during the growing season at about six-week intervals, depending on weather conditions and fertility levels. The best quality hay is obtained when cut at the boot stage with crude protein (CP) of up to 17%. However, the CP levels are lowered when cutting is delayed and can be reduced to less than 10% (IL-NRCS-USDA 2000). Eastern gamagrass is also preserved as silage. Most of the research on EGG has focused on forage production and digestibility in cattle.

Little is known about how goats perform when fed EGG. Therefore, the objective of this research was to evaluate growth, feed intake and carcass characteristics of Boer cross goats fed different levels of EGG with concentrate.

Materials and Methods

The study utilized 18 intact Boer cross goats (4-5 months old) housed in individual pens and fed one of three dietary treatments: 80:20 (A); 70:30 (B); and 60:40 (C) (EGG: concentrate (Nutrena Sweet Stuff ™)) for 12 weeks. Water was provided *ad libitum*, and mineral blocks were placed in each pen. Feed intake and refusals were monitored daily and feed offered was adjusted on a weekly basis. Body weight was recorded weekly. Animals were slaughtered at the end of 12 weeks and pre and post transportation animal weights were taken to account for transportation stress. The animals were kept overnight in a holding facility and fasting body weights were recorded the following morning. After slaughter, carcasses were washed and hot carcass weights (HCW) were obtained before the carcasses were placed in a chill room kept at 4°C for 24 h. After chilling, the carcasses were weighed and the following parameters measured; cold carcass weight (CCW), carcass length, leg circumference, loin eye area and five specialty cuts (neck, shoulder, leg, loin, ribs). The weights of the liver, heart, lungs, viscera (intestine), kidney, pelt, testicles, head and feet were taken. After cold carcass weights were obtained (24 hrs after slaughter), the weights of the specialty cuts (shoulder, ribs, loin, leg and neck) were taken. The leg circumference and carcass length were measured using a tape and the loin eye area was ascertained using a grid.

Results and Discussion

Tables 1 and 2 show the nutrient composition of EGG and the concentrate used in the study. The nutrient compositions of the diets were similar to each other and met National Research Council (NRC) specifications. The Ca:P ratio of the three diets should be noted as they appear to be high. A Ca:P ratio of 1.4:1 is reported as ideal for goats but higher ratios were observed in this study (http://home.btconnect.com/gnltd/vitminarticle.html). It should be noted that others have argued that high dietary Ca in goat diets can cause hemorrhagic conditions or interfere with other mineral absorption (Hall *et al.* 1991). However, no such conditions occurred during the study period. The Ca: P ratio of diet C is highest (3:1), followed by diet B (2.5:1) and the least is diet A (2:1). Yung-Keun and Thacker (2006) reported that increasing the Ca:P ratios in diets of weanling pigs resulted in better feed efficiency. Although the highest gains for this study were obtained when Ca:P ratios were highest, this might warrant some further study.

Although initial and final weights were not significantly different, total weight gain by the goats on the three EGG diets differed significantly ($p<0.05$) for the study (Table 3). Animals on diet C (60:40) had the highest total weight gain (19.0 lb) while diet B recorded the least weight gain (13.0 lb). This implies that a rapid growth of Boer cross goats can be obtained when fed a diet containing a 60:40 EGG to concentrate. For this diet, there was an average daily gain (ADG) of 3.3 0z. This rate of increase was 50% greater than either of the other two diets used in the study. Although there was a high ADG, there was a concomitant increase in intake. Animals fed diet C also had a significantly higher rate of intake of EGG compared to diets A and B. Furthermore, it should be noted that despite the smallest amount of weight gained by animals on diet B, the average daily feed intake was highest (2.6 lb). The

gain to feed ratio was significantly higher ($P<0.05$) for goats receiving diet C. This follows similar patterns for other forages supplemented with concentrate, whereby, a diet containing approximately 60% forage give the best results. It might be important that the diet containing the highest levels of EGG (80:20) be looked at from an economic point of view as it might be of interest to limited resource or small-scale goat farmers.

Table 4 shows the carcass weights of goats fed EGG. No significant differences were obtained for the various carcass parameters measured. Percent shrinkage of the meat was minimal for the various diets ranging from 0.35% (diet B) to 1.45% (diet C). Animals in diet A had the greatest leg circumference (1.3 in) while animals in diet C had the lowest (1.2 in). Diet did not affect loin eye area but animals on diet B had the longest carcasses (24.9 in) while those fed diet A had the shortest carcasses (23.6 in). There was no significance difference in all of the specialty cuts among the diets.

There was no significant difference in the non-carcass components (skin, feet, head, heart, lung, liver, kidney, viscera and testicles) among the diets (Table 5). However, the GI tract accounts for almost 30% of the animals' body weight. This is important because it represents an economic loss since most of this material is discarded. It should be noted that diet C had the least amount of GI tract. As was the case for fasted body weight (overnight withdrawal of feed), skin percent tended to be higher for diet B. Some of these internal organs are readily consumed by certain ethnic groups and can be an additional source of income for small-scale farmers. The liver, lungs, heart, kidneys, heads and feet are routinely processed and demands are high for these organs.

The loin represents the highest priced meat on the goat and the percentage resulting from diet C was the highest (Table 6). The legs/shoulders/ribs represent the next best prices obtained for chevon but showed no significant difference among the diets. Necks are the cheapest cuts and represents only 11% of carcass weight.

Conclusion

Eastern gamagrass shows significant potential as high quality alternative forage for goats. The gains obtained with EGG were comparable with bermudagrass when supplemented with concentrate (Bartlett et al. 2006). This study shows that EGG can be supplemented with concentrate at a 60:40 and provide significant increase in ADG of intact Boer crosses. Further analysis is needed to evaluate the economics of feeding various levels of eastern gamagrass in the diets of meat goats.

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Table 1. Chemical composition of eastern gamagrass and concentrate (Nutrena Sweet Stuff ™).

Nutrients	Eastern gamagrass	Sweet Stuff ™
Dry matter (%)	93.6	92.6
Crude protein (%)	12.4	13.6
NDF[1] (%)	68.0	45.0
ADF (%)	34.0	32.0
TDN (%)	52.7	55.5
Ca (ppm)	0.22	1.61
K (ppm)	2.12	1.18
Mg (ppm)	0.20	0.34
P (ppm)	0.24	0.28

[1]NDF, neutral detergent fiber; ADF, acid detergent fiber; TDN, total digestible nutrients.

Table 2. Chemical composition of different eastern gamagrass diets.

Nutrients	Diet A[1]	Diet B	Diet C
Dry matter (%)	93.42	93.31	93.21
Crude protein (%)	12.82	12.91	13.00
NDF (%)	63.40	61.10	58.80
ADF (%)	33.60	33.40	33.20
TDN (%)	53.24	55.52	53.81
Ca (ppm)	0.50	0.64	0.78
P (ppm)	0.25	0.25	0.26
K (ppm)	1.93	1.84	1.74
Mg (ppm)	0.23	0.24	0.26
Ca: P ratio	2: 1	2.5: 1	3: 1

[1]Diet A, 80:20; Diet B, 70:30; Diet C, 60:40 (eastern gamagrass: concentrate), NDF, neutral detergent fiber; ADF, acid detergent fiber; TDN, total digestible nutrients.

Table 3. Weight changes and feed intake of Boer goats fed eastern gamagrass.

Parameters	Diet A[1]	Diet B	Diet C
Initial body wt. (lb)	46.8[a]	49.2[a]	47.5[a]
Final body wt. (lb)	60.8[a]	62.2[a]	66.5[a]
Weight gain (lb)	13.4[a]	13.0[a]	19.0[b]
ADG[2] (oz/day)	2.4[a]	2.3[a]	3.3[b]
ADI (lb/day)	2.3[a]	2.6[b]	2.5[b]
Gain: Feed ratio	0.07[a]	0.06[a]	0.09[b]

[1]Diet A, 80:20; Diet B, 70:30; Diet C, 60:40 (eastern gamagrass: concentrate).
[2]ADG, average daily gain; ADI, average daily intake.
Means with different letters in rows are significant at ($p<0.05$).

Table 4. Fasted, hot and cold carcass weights, carcass length, loin eye area and leg circumference of meat goats fed eastern gamagrass.

Parameters	Diet A[1]	Diet B	Diet C
Fasted weight (lb)	59.3	61.7	60.4
Hot carcass wt. (lb)	22.4	25.4	27.3
Cold carcass wt. (lb)	22.3	25.3	26.9
Carcass length (in)	23.6	24.9	24.5
Loin eye area (in)	1.2	1.4	1.3
LC[2] (in)	12.5	12.3	12.2

[1]Diet A, 80:20; Diet B, 70:30; Diet C, 60:40 (eastern gamagrass: concentrate)
[2]LC, leg circumference

Table 5 Non-carcass components of meat goats fed eastern gamagrass diets.

Parameters	Diet A[1]	Diet B	Diet C
	------------------------% of cold carcass weight-------------------------		
GIT[2]	29.20	29.21	26.99
Skin	10.29	11.02	10.55
Head	7.48	7.64	7.78
Feet	2.59	2.77	2.84
Liver	1.30	1.32	1.39
Testicles	1.12	1.06	1.08
Lung	0.83	0.71	0.94
Heart	0.38	0.42	0.45
Kidney	0.29	0.31	0.34

[1]Diet A = 80:20; Diet B = 70:30; Diet C = 60:40 (eastern gamagrass: concentrate);
[2]GIT, gastro intestinal tract

Table 6. Specialty cuts of meat goats fed eastern gamagrass diets.

Specialty cuts	Diet A[1]	Diet B	Diet C
	-------------------------% of cold carcass weight-----------------------		
Rib	18.77	18.72	18.27
Loin	16.45	17.40	18.12
Shoulder	21.23	20.95	20.98
Neck	11.53	10.98	10.80
Leg	32.25	32.58	32.40

[1]Diet A, 80:20; Diet B, 70:30; Diet C, 60:40 (eastern gamagrass: concentrate).

Eastern Gamagrass: The Effects on Meat Goats Fed a Fat-Supplemented Diet

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Abstract

The objective of this study was to determine the effects of feeding eastern gamagrass [*Tripsacum dactyloides* (L.) L.] (EGG) in a diet supplemented with varying levels of a vegetable fat (peanut oil) on the growth performance and carcass characteristics of meat goats. The study utilized 24 intact male Boer-cross goats (4-5 months old), assigned to one of four dietary treatments: diet A (control, no added fat), diet B (1.6% added fat), diet C (3.2% added fat) and diet D (4.8% added fat). Goats were randomly assigned to individual pens and fed a 60:40 (eastern gamagrass: concentrate) ration twice daily at 5% of their body weight for 12 weeks. Water and mineral blocks were provided ad libitum. Feed intake and refusals were monitored daily and body weights recorded weekly. Goats were slaughtered at the end of the study. No significant differences were observed among the diets for initial body weight (BW), final BW, fasted BW, hot carcass weight (HCW) or cold carcass weight (CCW). Results showed no significant differences in total weight gain or average daily gain (ADG) among the diets. Average daily intake (ADI) decreased as the level of fat in the diets increased. Diet A had a significantly ($P<0.05$) higher ADI (29.2 oz/day) than goats in diets C and D. Carcass length, loin eye area, leg circumference, and specialty cuts, showed no significant differences among diets. However, goats in diet D showed significantly higher ($P<0.05$) leg percentages (32.78%) than those in diet B. Diets did not significantly impact carcass characteristics or growth performance of the goats.

Key words: Body wt, Boer goats, carcass wt, Eastern gamagrass

Introduction

Goats are one of the smallest domesticated ruminants in the world. Goats have been domesticated longer than sheep and cattle. Goats can be managed for the production of meat, milk and fiber. Goat carcasses differ drastically from other ruminants because of the fat deposition within the animal. Goats tend to deposit more fat internally rather than subcutaneously and intramuscularly, resulting in far less marbling than cattle and sheep. Because of this, goat carcasses are 10 and 19% leaner, and have a 47 to 54% lower fat content than beef and mutton (Gelaye and Amoah 2006). In addition, goat meat has 40% less saturated fat than chicken without the skin (Adrizzo 1999). However, one of the characteristics of chevon is its toughness due to the lack of marbling. Over the years, researchers have investigated ways to enhance the quality of beef, pork, chicken and other meat sources, by utilizing a combination of different types of feeds and supplements, however, very limited information exists about goat meat. With consumers becoming more aware of the health benefits of chevon, goat production in the United States is growing at a rapid pace, mostly by limited resource farmers. Because of this fact, they are also looking for more economical ways to produce a high quality product. Alternative forages like eastern

gamagrass can serve as a source of forage (hay) during the winter months when other grasses are not available.

Several researchers have evaluated fat supplementation in the diets of ruminants and non-ruminants. Pettigrew and Moser (1991) noted that adding fats to the diets of growing-finishing pigs typically improves average daily gain (ADG) and gain:feed ratio (G:F) while reducing average daily intake. However, Tokach et al. (1995) found that increasing soybean oil as a source of fat in the diet of pigs had no influence on ADG, but G:F was significantly improved. De la Llata et al. (2001) concluded that adding up to 6% fat in the diet of pigs consistently improved feed efficiency. It was reported by Nelson et al. (2004) that supplementing the diet of cattle with restaurant grease had increased G:F but decreased beef firmness score.

Eastern gamagrass has been widely reported as being one of the more palatable and productive warm-season grasses of the southeastern United States and serves as an excellent source of forage for all classes of livestock (Dewald and Louthan 1979). Most studies utilizing eastern gamagrass have been done with cattle, for example, the performance of steers fed eastern gamagrass was evaluated by Aiken (1997) and he found that there was an increase in live weight gain. Very limited information is available on the performance of goats fed eastern gamagrass or supplemental fat source. In order to enhance the taste and appeal of chevon to a wider range of health conscious consumers, this study was designed to determine if feeding an eastern gamagrass diet supplemented with varying levels of a vegetable fat, would improve the overall acceptability of chevon as a suitable alternative to other red meats.

Materials and Methods

This study was conducted for 12 wks utilizing 24 newly weaned Boer cross male goats about 3.5 months old and averaging 38.6 lb. The animals were quarantined for 3 wks after which they were randomly assigned to individual pens and offered one of four dietary treatments. Water and mineral blocks were provided ad libitum. There were 6 goats per treatment. The diets used in this study were: (Diet A) 60:40 EGG to concentrate (Nutrena Sweet Stuff ™) with no fat supplementation (control), (Diet B) 60:40 EGG to concentrate with 1.6 % added fat (peanut oil), (Diet C) 60:40 EGG to concentrate with 3.2 % added fat and (Diet D) 60:40 EGG to concentrate with 4.8% added fat. Peanut oil was used as the fat supplement in this study and was added to the concentrate fed. The amount of feed offered was based on 5% of the goats' body weight and feed offered was adjusted weekly based on feed refused and body weight gain. The animals were fed twice daily and feed intake and refusals were monitored daily. Body weights were recorded on a weekly basis.

At the end of the study, all the animals were slaughtered at Fort Valley State University, GA, abattoir facilities. Pre- and post-transportation animal weights were taken to account for transportation stress as described by Kannan et al. (2000). The animals were kept overnight in a holding pen and fasting body weights were recorded the following morning. Gregory (1998) reported that pre-slaughter fasting helps to reduce carcass contamination with gut contents at the time of slaughter. After slaughter, all carcasses were washed and hot carcass weights (HCW) were obtained before the carcasses were placed in a chill room kept at 4°C for 24 h. After chilling, the carcasses were weighed and the following parameters measured; cold carcass weight (CCW), carcass length, leg circumference, loin eye area and five specialty cuts (neck, shoulder, leg, loin, ribs). Other data collected were;

average daily gain (ADG), average daily intake (ADI), initial body weight (BW), and final BW. All data collected in this study, were analyzed using the general linear model (GLM) procedure (SAS 2001). Where ANOVA showed significance, means were separated using Tukey's studentized range test (Steele and Torrie 1980).

Results

There were no significant differences among diets as they relate to initial BW, final BW and total weight gain (Table 1). The similarities in initial BW show that goats were evenly distributed among the treatments. However, supplementing the diets with fat did not significantly improve growth rate. Table 2 showed that ADG was significantly ($P<0.05$) higher for the control group (no added fat) than goats receiving the highest level of fat, with 3.44 oz and 2.52 oz for Diets A and D, respectively. Diet C was similar to the control with 3.40 oz. Goats on Diet A consumed a significantly higher ($P<0.05$) amount of feed (1.82 lb) than those given the other diets. There was a decreased in intake as the level of fat was increased in the diets. Although goats on Diet A ate more and gained more weight, those on Diet C were more efficient in their conversion as is apparent by the gain to feed ratio (G:F). There were no significant differences among the diets for fasted BW, HCW and CCW (Table 3); however, there was a tendency for those fed the highest level of fat to perform below the other groups. Specialty cuts were expressed as a percent of CCW and are shown in Table 4. Goats in Diet D showed a significantly higher ($P<0.05$) percent of leg cut (32.78%) than those on Diet B (30.74%), but was not different from goats in Diets A and C. All other cuts did not differ significantly.

Discussion

Although there was no significance difference among most of the major parameters measured in this study, some trends were observed. The goats supplemented with the higher levels of fat gained less and had lower final body weights when compared to the control group. Average daily gain was not improved with the addition of fat in the diet. These results agree with reports by Tokach et al. (1995) who noted supplementing the diet of pigs with fat did not influence ADG. However, reports by Pettigrew and Moser (1991) showed that ADG was increased in pigs fed supplemental fat. Moreover, since ruminants and non-ruminants utilize fat differently, that could explain the results. Also, the type and level of fat supplied could explain the differences in these reports. In this study, ADI decreased as the level of fat increased in the diets. Pettigrew and Moser (1991) also reported a decrease in ADI when supplemental fat was fed to pigs. This reduction in intake could be as a result of a denser diet. In addition, the high fat in the diet may have affected the microflora of the rumen. Although not significant, the G:F ratio was better for goats on diet C than the control group in this study. Nelson et al. (2004) reported a linear increase in G:F as fat was increased in the diets of cattle. The results of the specialty cuts were similar to results obtained by Faucette (2005) (unpublished data). These researchers found no significant differences when goats were fed a diet containing eastern gamagrass.

Conclusion

The results of this study indicated that supplementing the diet of goats with fat did not significantly influence overall performance; however; goats in Diet C (3.2% added fat) exhibited the most favorable results among the diets that were supplemented with fat.

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Table 1. Mean initial body weight, final body weight, and total weight gain of meat goats fed eastern gamagrass diet supplemented with varying levels of fat

	Diets[a]			
Parameters[b]	A	B	C	D
Initial BW (lb)	39.84 ± 2.73	38.85 ± 2.65	39.66 ± 2.14	35.65 ± 2.58
Final BW (lb)	58.51 ± 2.56	58.16 ± 2.89	55.67 ± 2.91	49.34 ± 1.92
Total Gain (lb)	18.67 ± 1.01	16.84 ± 0.95	18.50 ± 1.87	13.67 ± 1.61

[a] Diet A, control no fat, Diet B, 1.6% added fat, Diet C, 3.2% added fat, Diet D, 4.8% added fat

Table 2. Mean average daily gain, average daily intake, and gain:feed ratio of meat goats fed eastern gamagrass supplemented with varying levels of fat

	Diets[a]			
Parameters[b]	A	B	C	D
ADG (oz/day)	3.44±0.19	3.10±0.17	3.41±0.35	2.52±0.30
ADI (oz/day)	29.2±1.58	23.96±1.46	22.58±1.29	18.38±0.94
G/F ratio	0.12±0.01	0.13±0.01	0.15±0.02	0.14±0.02

[a] Diet A, control no fat, Diet B, 1.6% added fat, Diet C, 3.2% added fat, Diet D, 4.8% added fat

[b.] ADG, average daily gain; ADI, average daily intake; G/F ratio, gain/feed ratio.

Table 3. Mean fasted body weight, hot carcass weight, and cold carcass weight of meat goats fed eastern gamagrass supplemented with varying levels of fat

	Diets[a]			
Parameters[b]	A	B	C	D
FBW (lb)	53.66 ± 2.60	51.34 ± 2.40	53.84 ± 2.45	46.50 ± 1.57
HCW (lb)	24.16 ± 1.30	26.68 ± 3.64	22.58 ± 1.38	19.25 ± 1.12
CCW (lb)	23.26 ± 1.28	22.00 ± 1.68	22.00 ± 1.39	18.23 ± 1.10

[a] Diet A, control no fat, Diet B, 1.6% added fat, Diet C, 3.2% added fat, Diet D, 4.8% added fat

[b.] FBW, fasted body weight; HCW, hot carcass weight; CCW, cold carcass weight

Table 4. Mean percent of specialty cuts of goats fed eastern gamagrass diet supplemented with varying levels of fat.

	Diets (%)[1]			
Parameters	A	B	C	D
Leg	32.06 ± 0.56[ab]	30.74 ± 0.33[b]	31.60 ± 0.14[ab]	32.78 ± 0.40[a]
Rib	18.80 ± 0.52	19.38 ± 0.40	19.05 ± 0.45	19.11 ± 0.35
Shoulder	21.01 ± 0.43	20.32 ± 0.42	19.88 ± 0.41	20.03 ± 0.14
Loin	14.38 ± 0.31	15.07± 0.31	14.81 ± 0.14	14.84 ± 0.25
Neck	5.05 ± 0.33	4.93 ± 0.22	4.50 ± 0.35	4.89 ± 0.34

[a] Diet A, control no fat, Diet B, 1.6% added fat, Diet C, 3.2% added fat, Diet D, 4.8% added fat

[a, b] Within a row, means with the same letter are not significantly different (*P<0.05*)

Genetics

Genetic Diversity of Switchgrass Populations in the Northeastern United States

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Introduction

Although a significant amount of genetic diversity exists within switchgrass (*Panicum virgatum* L.), little research has been conducted on the level of genetic diversity and local adaptation among different populations/ecotypes of switchgrass currently recommended for habitat restoration in the Northeast region of the US. Switchgrasses are divided into upland and lowland ecoptyes. Upland ecotypes are commonly octaploids (2n=8x=72) and occasionally hexaploids (2n=6x=54) and are shorter, finer stemmed and more adapted to drier habitats (Lewandowski et al., 2003). The lowland ecotypes are typically tetraploid (2n=4x=36) and are coarse-stemmed, tall growing and more robust than the upland ecotypes (Lewandowski et al., 2003). The objectives of the study were to determine molecular and morphological differences within and between 14 different switchgrass populations.

Key words: Genetic diversity, molecular markers, morphological markers, switchgrass

Materials and Methods

Switchgrass seed from 14 populations were obtained from various sources. 'Carthage', 'Timber', 'Contract', 'Shelter' and 'High Tide' germplasm sources were obtained from the USDA-NRCS Plant Materials Center in Cape May NJ and represented northeastern ecotypes. All of the additional germplasm sources ('Caddo', 'Shawnee', 196, Pav12, Turkey, 'Sunburst', 'Kanlow', 'Pathfinder', and 'Blackwell') were obtained from the Plant Introduction (PI) collection curated by the Germplasm Resources Information Network (GRIN) and included standard cultivars developed in the midwest and other germplasm sources from other countries. Seed of each population was germinated in Pro-Mix HP (K.C. Shafer, York, PA) in 12 x 15 inch flats. Individual plants were transplanted to 48-celled flats and held under greenhouse conditions for approximately 8 weeks. Plants were transplanted to a spaced-plant nursery in the spring of 2005 at the Rutgers University Plant Biology Research and Extension Farm at Adelphia, NJ. Morphological measurements were taken on 12 individuals from each of the 14 different switchgrass populations. Measurements included plant height, panicle height, and flag leaf height, length and width. Plant height was measured on an individual plant basis for one measurement per plant. The other measurements were taken from three panicles from each of the 12 plants per population and averaged for one measurement per plant. Leaf tissue was also collected from the same 12 individuals from each population for molecular marker analysis. DNA was isolated from leaf tissue using the Sigma® GenElute™ Plant Genomic DNA Miniprep kit (Sigma-Aldrich Co., St. Louis, MO).

Publicly available microsatellite (SSR) markers specific for switchgrass were utilized for the molecular marker analysis (Tobias et al, 2006). Approximately 32 SSR primer pairs were tested for polymorphism on the 12 individuals from each population totaling 180 individual samples. SSR markers were genotyped on an ABI 3130 genetic analyzer. Morphological and marker data was analyzed using the program *structure* (Pritchard et al., 2000) which identifies clusters of related individuals from multilocus genotypes. The full data set was analyzed for all models from K=1 through to 14.

Results and Discussion

Significant morphological and molecular differences between switchgrass populations were observed. *Structure* analysis of morphological data separated the populations into distinct groups with the biggest distinction occurring for K=2. 'Kanlow' and 'Timber' grouped together as a distinct group based on morphological measurements. These two populations looked phenotypically similar and were very tall stiff plants compared to the other populations evaluated. All other entries shared some similarities however some further group distinctions were evident. 'Pathfinder', 'Contract', and 'Blackwell' had some characteristics in common. 'Caddo', 'Shawnee', 196, Pav12, Turkey, 'Sunburst' and 'Shelter' also shared some similarities. The morphological analysis did not seem to separate northeastern from Midwestern ecotypes. Molecular marker data is currently being evaluated and will be compared to results generated from morphological characteristics.

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Switchgrass Gene Pools for Conservation and Restoration

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Abstract

Panicum virgatum L. (switchgrass) is a perennial grass native to the North American tallgrass prairie and broadly adapted to the central and eastern USA. Movement of plant materials throughout this region creates the potential of contaminating local gene pools with genes that are not native to a locale. The objective of this study was to determine if importation of non-local populations in the northern and central USA has significant potential to contaminate local gene pools contained at prairie-remnant sites. Forty-six prairie-remnant populations and 11 cultivars were analyzed for random amplified polymorphic DNA (RAPD) markers. Although there was significant population differentiation, little of this variation was associated with geographic regions. There was very little spatial variability and only a small amount of variability was associated with geographic distance, providing only weak support for isolation by distance. A small amount of population differentiation was associated with hardiness zones and ecoregions, suggesting that a recent proposal to use these two criteria for defining plant adaptation regions has merit for defining restoration seed zones of switchgrass. Cultivars of switchgrass cannot be differentiated from prairie-remnant populations on the basis of RAPD markers, indicating that they are still highly representative of natural germplasm. Seed sources of switchgrass can be moved considerable distance within hardiness zones and ecoregions without causing significant contamination, pollution, swamping, or erosion of local gene pools.

Key words: DNA markers, genetic conservation, prairie restoration

Introduction

Switchgrass is native to the tallgrass prairie of the central USA. It can be found in parairie remnants and under cultivation from the Rocky Mountains to the Atlantic Seaboard, from Nova Scotia to Florida, and from Saskatchewan to Arizona. Switchgrass is adapted to a wide range of habitats and ecosystems in eastern North America and is used for hay production, grazing, soil conservation, and prairie restoration.

Some of these uses are potentially in conflict with each other. Hay fields, whether intended for livestock or bioenergy production, and pastures are generally established with seed of improved cultivars. Switchgrass cultivars derive from two sources: seed increases of collections made from prairie-remnant populations and populations created by selection and breeding. Prairie-remnant populations that bear a cultivar name represent a wide range of ecosystems east of the Rocky Mountains. These cultivars were not derived by selection and breeding and, to the extent that seed production is carefully controlled, directly represent natural *Switchgrass* populations. Cultivars derived from selection and breeding largely

originated from prairie-remnant populations of the Great Plains. Because switchgrass breeding did not begin in earnest until the last quarter of the 20th century and breeding cycles require many years, these cultivars are not far removed from wild populations of switchgrass (Alderson and Sharp 1994; Vogel 2004). Both types of named cultivars were released for certified seed production after extensive evaluation for persistence, forage yield, and other agronomic traits in their intended area of use. The purpose of the cultivar seed certification process is to maintain genetic integrity of a switchgrass population across generations and years.

Restoration biologists usually prefer local germplasm for conservation and restoration, largely based on the assumption that local germplasm is better adapted than germplasm from other regions (Clewell and Rieger 1997; Lesica and Allendorf 1999; Montalvo et al. 1997). In some regions, this assumption has led to regulations stipulating the use of local germplasm (Clewell and Rieger 1997; Jones 2003; Rogers and Montalvo 2004). Little or no testing of the germplasm is conducted and consequently, the adaptation range of local germplasm is unknown. Prairie restoration and the use of native grasses for landscaping and conservation have become much more common in recent years, creating a need for scientific data on the importance of local populations, the geographic definition of local regions, and the genetic composition of local populations (Clewell and Rieger 1997; Lesica and Allendorf 1999; Montalvo et al. 1997). Local populations are often difficult to define (Rogers and Montalvo 2004, p. 21), leading to potentially arbitrary boundaries.

Seed orchards, established from seed collected on prairie remnants, have been used as a long-term source of seed for conservation or restoration purposes within narrowly defined geographic regions. These seed populations are generally harvested or collected by hand and threshed and cleaned using fairly small-scale equipment. Due to narrowly defined geographic ranges and to the minimal use of mechanization for seed production and processing, seed prices of local collections tend to be extremely high. In some cases, public agencies have taken on this responsibility in order to make these seed sources available for local landowners and public lands.

Conflict arises between these two uses because seed from cultivars or from prairie remnants outside of a small region are considered to be undesirable for conservation or restoration purposes. Conservationists criticize such germplasm as unacceptable, because it contains genes and traits from other regions, it does not represent the local region either genetically or phenotypically, and it may lead to outbreeding depression and genetic pollution in local populations (Lesica and Allendorf 1999; Montalvo et al. 1997). Because nothing is known about the genetic structure of prairie-remnant switchgrass populations, there is no scientific evidence to either support or refute this criticism. The potential consequences of gene flow from non-native germplasm into local germplasm pools are largely unknown (Rogers and Montalvo 2004 p. 131).

The objective of this study was to identify structural patterns and spatial variation for molecular markers of switchgrass populations from the northern and central USA. The presence of structural patterns or spatial variation would indicate that these criticisms are well founded, that there are different switchgrass gene pools in different regions of the northern and eastern USA. The degree to which spatial patterns exist among prairie-remnant populations will partly determine the limits with which gene pools can be exchanged among regions without significantly contaminating local gene pools. Conversely, lack of spatial variation will suggest that these fears are unfounded for this species and local regions for

conservation or restoration using switchgrass germplasm may be broader than perceived by many restoration biologists.

Materials and Methods

A total of 78 switchgrass collections were made from 59 sites in Minnesota, Wisconsin, Michigan, Indiana, Ohio, and New York in 1997 and 1998. Sites were identified as prairie remnants based on local agency records. Some of the collection sites were sufficiently large or variable to warrant multiple collections from these sites. Multiple collections from a site were generally made when there was a significant change in soil type, aspect, or habitat. Seeds were stored at room temperature until December 1998. A sample of seed of each accession was chilled at 3°C for 3 weeks and planted in plastic seedling tubes containing a 1:1 mixture of silt loam soil and peat moss. Seed dormancy problems limited the study to a total of 46 accessions from 34 sites (Fig. 1).

In January 1999, seedlings of 11 cultivated switchgrass populations (Blackwell, Cave-in-Rock, Pathfinder, Shawnee, Shelter, Summer, Sunburst, Trailblazer, NE-HZ4, NEearly-HYC3-HDC2, and NE28-HYC3-HDC2) were germinated without pre-chilling. The cultivars represented both seed increases from prairie remnants and the products of breeding programs. Ten to 20 seedlings were used to represent each cultivar or prairie remnant population. A total of 818 seedlings were raised in the greenhouse for DNA extraction.

Each plant was harvested for DNA extraction and analysis using techniques described by Johns et al. (1997). A total of 117 different DNA fragments were analyzed, scoring each plant for presence or absence of the fragment, which represents a portion of a gene. This created a matrix of zeros and ones (zero for "absent" and one for "present). There were 818 x 117 values in the matrix (818 plants x 117 DNA markers). The matrix of zeros and ones was analyzed by standard statistical approaches, intended to identify sources of variability, structural patterns, and relationships of this variability and structure to geographic variables, such as USDA hardiness zones (temperature and daylength) or Bailey's ecoregions (soil type and pre-settlement historic vegetation type).

Results and Discussion

The variance analysis revealed significant marker variability between cultivars and prairie-remnant populations, but it explained less than 1% of the total marker variation (Table 1). Furthermore, the structure of marker variability for cultivars and prairie-remnant populations was identical. There was no marker variability associated with USDA hardiness zones or ecoregions for prairie-remnant populations (PRP), nor for the diverse regions of cultivar origin. There was significant marker variability among prairie-remnant populations within plant adaptation regions and among cultivars within origins, accounting for 32 and 29% of the total marker variability within these two groups. These results indicate that both cultivars and prairie-remnant populations have high levels of within-population variability, indicating a long-history of gene flow between populations. There were no DNA fragments found to be unique to any single or small number of populations.

The lack of genetic differentiation between the two types of cultivars can be observed in Fig. 2. Distributions of plants show considerable overlap within regions, such as hardiness zone 6 in the Eastern USA (the PRP-seed-increase cultivar Cave-in-Rock vs. the bred cultivar Shelter) hardiness zone 4 (the source-identified Northern Great Plains HZ4 gene pool vs. the bred cultivar Sunburst), and hardiness zone 6 in the Great Plains (the PRP-seed-

increase cultivar Blackwell vs. the bred cultivars developed in Nebraska). These overlapping distributions also illustrate the lack of ecoregion or hardiness zone differentiation among cultivars. Similarly, average gene diversity was similar between cultivars such as Cave-in-Rock, derived as seed increases of prairie-remnant populations (0.26 ± 0.02), and cultivars derived by selection and breeding (0.24 ± 0.01).

The lack of ecoregion or hardiness zone differentiation for prairie-remnant populations is illustrated in Fig. 3. Despite this lack of molecular differentiation (Table 1), some structure exists among these prairie-remnant populations. Approximately 75% of the plants form a central core of plants with common genetic profiles. Plants from EBFC-4 form a horizontal axis along Dimension 1, while plants from EBFC-6 and EBFO-6 form a nearly vertical axis along Dimension 2. Finally, most of the plants from EBFC-5 form an axis from upper left to lower right, approximately 45° offset from the other two axes. These axes illustrate a fundamental difference in the structural distribution of plants from these regions. Thus, while plants from these groups are not differentiated from each other, on the average, their distributions are not strictly coincident with each other.

A direct comparison of Figs. 2 and 3 illustrates the huge overlapping distributions of the prairie-remnant populations and the cultivars. A relatively small number of plants from cultivars fell outside the distribution of the prairie-remnant populations, 22 plants in the lower middle and three plants in the upper left of Fig. 2, representing four of the six cultivar groups. Thus, only 15% of the plants from the cultivars fell outside the range of the prairie-remnant populations. However, this does not represent a true differentiation between prairie remnants and cultivars, because the PRP-seed-increase cultivars and the bred cultivars were almost completely coincident in Fig. 2. Thus, the bred cultivars did not contain any genotypes unique to this species or outside the range of prairie-remnant plants. Switchgrass cultivars could not be distinguished from prairie-remnant populations on any genetic basis.

The limited breeding history of switchgrass has not narrowed the genetic variability among or within cultivars, as indicated by the similar levels of within-population marker variability for these three groups. Similarly, average gene diversity was approximately equal for bred cultivars and prairie-remnant populations of both big bluestem, *Andropogon gerardii* Vitman, and Indiangrass, *Sorghastrum nutans* (L.) Nash (Gustafson et al. 2004). Gene diversity was also similar within prairie-remnant populations from prairies of vastly different size, indicating that small prairie remnants can be valuable sources of genetic diversity (Gustafson et al. 2004).

The lack of marker variation between the three groups (bred cultivars, PRP-seed-increase cultivars, and prairie-remnant populations) indicated little genetic differentiation among these groups. To many people, this result may seem at odds with the concept of "improved" cultivars. It begs the question, how can an "improved" cultivar, one that has a supposed agronomic advantage over natural germplasm, be genetically undifferentiated from natural germplasm? The answer is that agronomic changes during the breeding process are very small, accumulated is significant amounts only over many generations of breeding and selection. During the short history of switchgrass breeding small gains have been made for traits such as biomass yield, disease resistance, and forage quality, but these changes are very small and have not altered the physical appearance or the fitness of switchgrass cultivars from their wild counterparts. Nor has this agronomic selection created any new or unique genotypes that could not have occurred in the wild. In addition, switchgrass has a self-incompatibility system that favors cross-pollination (Martinez-Reyna and Vogel 2002).

Self-incompatibility systems generally maintain 3 to 10 times more genetic variability within populations than among populations (Gustafson et al. 1999, 2004; Huff et al. 1993; Huff et al. 1998). Species that are characterized by self-incompatibility systems generally have a long history of gene flow between populations.

Selection, drift, and migration have all likely been major forces driving the observed structure of this remnant population. Historically, migration may be the most important of these forces, having acted to homogenize the population across landscapes, minimizing genetic differentiation on a regional scale. Migration was likely more frequent when the tallgrass prairie ecosystem was more broadly abundant across the central and eastern USA, facilitating gene flow by pollen movement across a more-of-less continuous ecosystem. The lack of strong evidence for isolation by distance suggests that migration is no longer of major importance in regulating population structure of switchgrass in this region.

Habitat fragmentation has likely resulted in population differentiation through the processes of drift and selection (Hanski 1991; Husband and Barrett 1996). Local differentiation, which accounts for all population differentiation observed in this study, may arise from chance events known as genetic drift, which results from small founder populations and habitat fragmentation. Drift may have occurred in members of the tallgrass prairie as this ecosystem advanced north following the last glaciation period. Population differentiation also may arise from selection for adaptation to specific environmental factors, such as soil type, habitat, and coexisting vegetation. Because of the broad adaptation range of switchgrass ecotypes and cultivars (Casler 2005; Casler et al. 2004) selection may be of secondary importance in creating local differentiation. Selection has acted on a large regional scale, differentiating populations for flowering time, photoperiodism, cold tolerance, and heat tolerance, strongly on a latitudinal gradient and weakly on a longitudinal gradient (Casler 2005; Casler et al. 2004; McMillian 1959, 1965; McMillian and Weiler 1959).

Results from both big bluestem and Indiangrass suggest a similar population structure of a remnant population. Although the number of populations and the sampling area was more limited than for our study of switchgrass, there was little spatial variation on a relatively narrow landscape scale, but some population differentiation was observed between populations from Illinois vs. the Great Plains (Gustafson et al. 1999, 2004). These three species share numerous life-history traits, as well as a long evolutionary history, suggesting that evolutionary forces and habitat fragmentation have probably had similar effects on structure of prairie-remnant populations of all three species.

Plant Adaptation Regions, combining hardiness zones with plant ecoregions (Vogel et al. 2005), provide a framework to identify gene pool localities for conservation and restoration efforts. The USDA hardiness zones are defined largely by gradients of 5.5°C (42°F; Cathey 1990), creating a system of survival and adaptation zones associated with phenotypic variability for adaptation traits such as flowering time, photoperiodism, cold tolerance, and heat tolerance (Casler et al. 2004). Bailey's ecoregions are defined by pre-settlement dominant successional vegetation classes, which are correlated with major soil taxa (Bailey 1998). Digitization of both USDA hardiness zone and Bailey's ecoregion boundaries using Geographic Information System (GIS) software allows additional prairie-remnant populations to be easily classified, providing a distinct advantage to the PAR system (Vogel et al., 2005). The PAR system of Vogel et al. (2005) is comparable to the "seed zone" system for conifers of the western USA (Johnson et al. 2004).

Plant Adaptation Regions can be used in conjunction with Jones' (2003) proposal of primary and secondary restoration gene pools (RGP). Jones (2003) defined the primary RGP as the target population itself or germplasm connected to it via pollen flow or seed dispersal. In many restoration situations, the target population itself doesn't exist, because of severe and/or long-term disturbance or habitat loss (eg. loss of the tall-grass prairie ecosystem to agriculture). Our results for switchgrass suggest that any prairie-remnant populations within the PAR can be used to represent the primary gene pool of that PAR. Restriction of a RGP to a narrowly defined region or habitat, as suggested by some authors (Kitzmiller 1990; Linhart 1995; Millar and Libby 1991) is unnecessarily restrictive for switchgrass. Because most of the genetic variability occurs within populations, a relatively small number of collection sites may be sufficient to maintain genetic variability of the gene pool. A multiple-origin polycross would provide a mechanism to create a source-identified population, equally represented by any number of collection sites within the PAR (Jones 2003). A polycross of two genetically heterogeneous local populations may be sufficient to maintain genetic diversity of a restoration gene pool (Gustafson et al. 2002). Standardized, commercial seed production practices should be utilized to increase seed in a representative environment within the PAR, minimizing the potential for selection (Vogel 2004). Seed orchards should be sufficiently large to minimize genetic drift and provide a source of seed adequate for the region's conservation and restoration needs (Knapp and Rice 1994). Partnerships between agencies responsible for conservation and restoration, state crop improvement organizations, and private organizations with experience in seed production may prove valuable in developing an affordable and reliable source of high-quality seed for restoration.

Conclusions

The results of this study indicate that prior, current, or future use of switchgrass cultivars for restoration purposes will not contaminate, pollute, swamp, or disrupt local gene pools. Plant genotypes contained within cultivars are not unique to these cultivars, but are broadly representative of switchgrass germplasm from prairie-remnant populations. There are no "non-native genes" in switchgrass cultivars, as Millar and Libby (1989) suggested for non-native *Pinus muricata* of unknown origin. Although switchgrass cultivars could also be included in multiple-origin polycrosses used as restoration gene pools (Jones 2003), the use of bred cultivars is not necessary for this purpose. Because of the huge amount of within-population genetic variability in this species, a relatively small number of source-identified populations should prove sufficient to represent any given PAR. There is, however, no reason to exclude PRP-seed-increase cultivars, as they do not represent any form of breeding, selection, or human-based improvement. Those who criticize the use of cultivars for restoration purposes should recognize the dual use of this term and the fact that some cultivars are no different than any source-identified prairie-remnant population. The results of this study indicate that currently available cultivars developed by breeding have not been altered to the extent that they should be arbitrarily excluded from conservation plantings.

While it is unfortunate the term 'cultivar' has been applied to seed lots that represent prairie-remnant populations without conscious human-applied selection pressures, we must learn to live with the duality of this term. Rogers and Montalvo (2004) also suggest that this term is a misnomer for natural-track germplasm, most likely a persistent remnant of the seed certification process for agricultural cultivars. We suggest that nomenclature for restoration

gene pools based on source-identified germplasm should reflect their origin and region of intended use. For example, a restoration gene pool of switchgrass for hardiness zone 4 of the Eastern Broadleaf Forest ecoregion could be termed: RGP-HZ4-Eastern #1 switchgrass. Similarly, for HZ5 of the Prairie Parkland ecoregion: RGP-HZ5-Prairie #1. While this nomenclature is a bit cumbersome, it is sufficiently flexible and informative to allow the use of multiple restoration gene pools for a region, as new germplasm is collected and added to the gene pool or as the gene pool may become subdivided according to additional edaphic or environmental factors, such as elevation, soil characteristics, or human-derived disturbances.

An unselected or natural-track RGP can be released under any one of four germplasm classes: source-indentifed, selected, tested, or cultivar (Jones and Johnson 1998; Rogers and Montalvo 2004). In this case, the 'selected' category refers to selection among ecotypes, but no intentional selection with in ecotypes. It should be pointed out that natural selection within an RGP is not necessarily undesirable, because it may allow a genetically broad RGP to adapt itself more favorably to a wide range of sites (Jones 2003; Jones and Johnson 1998; Kitzmiller 1990). The 'cultivar' category is identified as 'natural-track' to separate it from bred or manipulated cultivars, but this distinction is often lost during the seed multiplication and commercialization process (Alderson and Sharp 1994).

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Table 1. Analysis of molecular variance (AMOVA) for data from 117 random amplified polymorphic DNA (RAPD) markers collected on 818 switchgrass plants which were derived from 11 cultivars or 46 prairie remnant populations (PRP).

Source of variation †	df	Sum of squares	Variance component	P-value	Percentage of total variance
					%
PRP vs. Cultivars	1	211	0.31	0.0166	0.7
Plant Adaptation Regions (PAR)	5	657	0.09	0.2659	0.2
PRP within PAR	40	4649	7.21	<0.0001	16.7
Plants within PRP	607	9050	14.91	<0.0001	34.7
Cultivar origins (CO)	4	417	0.11	0.4213	0.3
Cultivars within CO	6	628	5.99	<0.0001	13.9
Plants within cultivars	154	2221	14.42	<0.0001	33.5
Total	817	17833	43.03		100.0

† Plant Adaptation Regions were defined as a combination of ecoregion provinces (Bailey 1998) and USDA hardiness zones (Cathey 1990), as shown in Fig. 1 and described in detail by Vogel et al. (2005). Cultivar origins were Northern Great Plains, Nebraska, Oklahoma, Illinois, and West Virginia.

Fig. 1. Albers equal-area projection of a portion of the North Central and Northeastern USA, showing the location of 34 prairie remnant sites that were the source of 46 switchgrass collections made in 1997 and 1998. The site to the east of the Michigan Lower Peninsula (HI) is on Hansen's Island in Lake St. Clair. USDA hardiness zones (HZ) 3, 4, 5, and 6 are identified on the map (Cathey 1990). All sites were located within the Eastern Broadleaf Forest (Continental) ecoregion, with the following exceptions: sites CH and RF in the Prairie Parkland (Temperate) ecoregion; sites AN, AS, MO, and SB in the Laurentian Mixed Forest ecoregion; and sites SA and YC in the Eastern Broadleaf Forest (Oceanic) ecoregion (Bailey 1998).

Fig. 2. Scatterplot of the first two multidimensional scales for 165 plants representing 11 switchgrass cultivars, grouped by a combination of ecoregions (Bailey 1998) and USDA hardiness zones (Cathey 1990): PPT = Prairie Parkland (Temperate) ecoregion, EBFC = Eastern Broadleaf Forest (Continental) ecoregion, and EBFO = Eastern Broadleaf Forest (Oceanic) ecoregion. Numbers refer to USDA hardiness zones. Closed symbols correspond to seed increases of prairie-remnant populations and open symbols correspond to cultivars created by conscious selection.

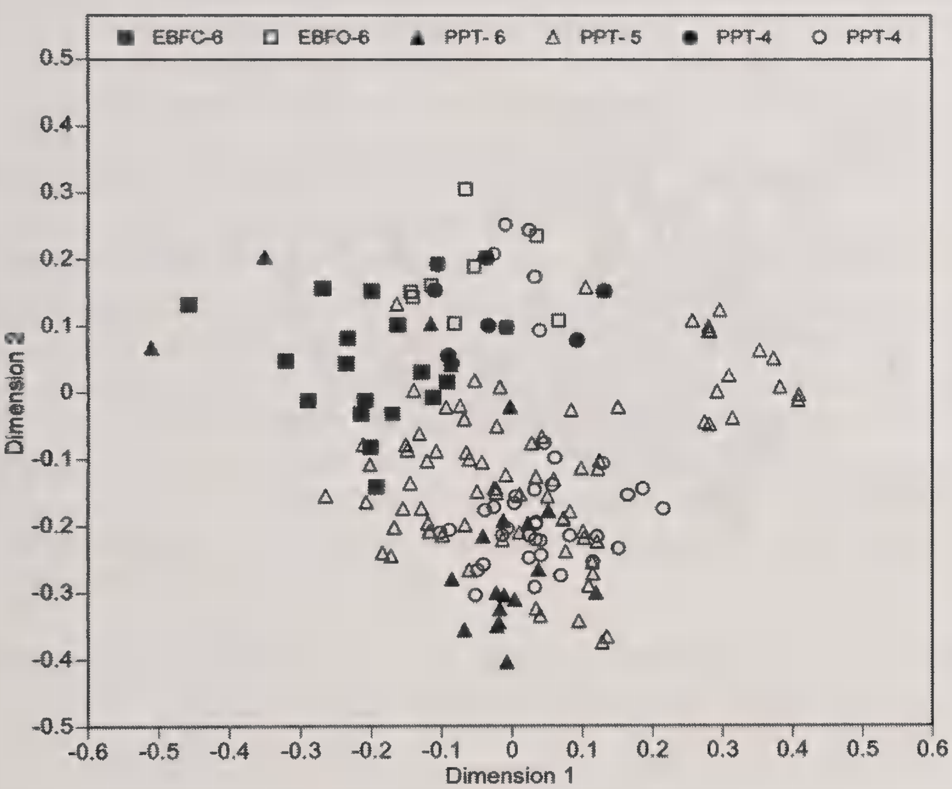
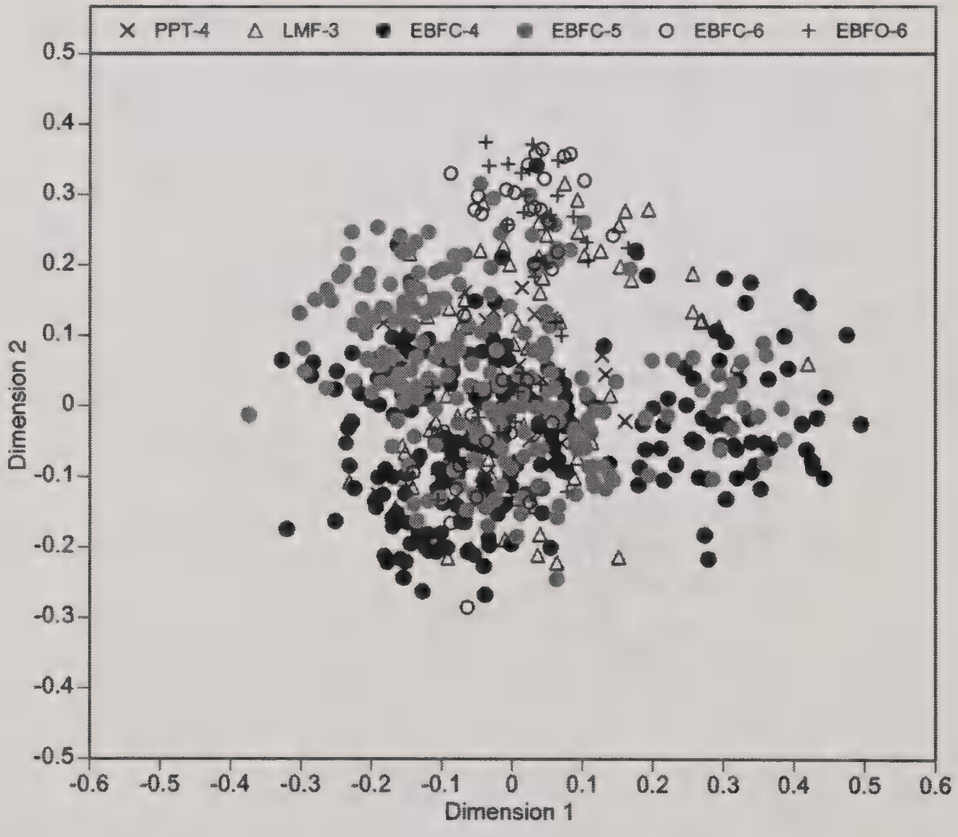


Fig. 3. Scatterplot of the first two multidimensional scales for 653 switchgrass plants representing six geographical areas defined by a combination of ecoregions (Bailey 1998) and USDA hardiness zones (Cathey 1990): PPT = Prairie Parkland (Temperate) ecoregion, LMF = Laurentian Mixed Forest ecoregion, EBFC = Eastern Broadleaf Forest (Continental) ecoregion, and EBFO = Eastern Broadleaf Forest (Oceanic) ecoregion. Numbers refer to USDA hardiness zones.



Relationships Between Geographic Distance and Genetic Differentation: Or, Why Don't You Write Home More Often?

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Genetic variation was surveyed within and between native populations of little bluestem (*Schizachyrium scoparium* (Michx.) Nash [=*Andropogon scoparius* Michx.]) and Virginia wildrye (*Elymus virginicus* L.), using random amplified polymorphic DNA (RAPD) markers. The native populations of each species included collections from both northeastern and midwestern regions within the USA. Analysis by molecular variance (AMOVA) technique showed that little bluestem populations were highly variable within populations whereas Virginia wildrye populations were relatively uniform within populations. Furthermore, when the two species were compared, an interesting relationship was observed between the genetic distance among populations and the geographic origin of the populations. Little bluestem exhibited a positive correlation and thus, its populations became more genetically different the further populations were separated by geographical distance. Virginia wildrye populations lacked such correlation and thus, populations between widely separated regions could exhibit genetic relationships that were, in some cases, more similar than populations within a region. Partitioning of genetic variability within and among populations across regions is, in large part, a function of the breeding system of the species. Little bluestem possesses an open-pollinated, outcrossing breeding system; whereas, Virginia wildrye is a self-pollinated, inbreeding species. Thus, the reproductive biology of native plants governs the genetic structure observed among populations within a species. As such, a species' reproductive biology is a vitally important parameter to consider when replenishing or replacing locally adapted gene pools.

Key words: Genetic variation, little bluestem, population genetics, Virginia wildrye

Germination, Establishment, and Weed Control

Response of Native Forbs to Pre-Emergent Treatment of Imazapic Herbicide

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Grassland restoration involves attempting to restore and/or re-create biologically diverse native plant communities. Herbicides are an important tool for removing competition from exotic species. Native plant mixes are often determined by the tolerance of species to the selected herbicide(s). Subsequent plantings are often necessary to increase native plant diversity, increasing management inputs and costs. Imazapic herbicide is widely used in grassland restoration projects. In spring 2006, we initiated a study testing responses of 22 native forbs to 2 and 4-oz pre-emergent treatments of imazapic. Sites were established in AL, KY, and IN to provide broad applicability of results. Seedling establishment and weed cover were monitored at 30 and 60 days, and at the end of the growing season. Information will provide managers a more encompassing list of species to include in initial plantings, increasing diversity and reducing costs of restoration projects.

Key words: Imazapic, native forbs, restoration, weed competition

Thistle Invasion Hinders Grassland Conversion

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In September 2004, a grassland conversion project was initiated in southeastern South Dakota. The site was hayed and four herbicide treatments were applied in fall 2004 and spring 2005 to test efficacy of each for removal of smooth brome (*Bromus inermis* Leyss.). Following spring treatments the site was planted with a CP25 native plant mix. Herbicide treated plots were severely invaded by thistle (*Carduus* and *Cirsium*). Control plots had little invasion by thistle. Removal of vegetation and chemical burndown facilitated invasion by thistle, limiting native plant establishment and requiring further management detrimental to native forb communities.

Key words: Herbicide, management, native vegetation, thistle

Determining the Effect of Age of Seed on Germination of Harrison Germplasm Florida Paspalum Select Release

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Florida paspalum [*Paspalum floridanum Michx.*] seed dormancy is a major obstacle in establishment of this multipurpose warm-season native grass. Age of seed and wet prechill treatment have shown to be beneficial in breaking seed dormancy in many grass species. The objective of this study was to determine the effect of seed age and cold, moist stratification on germination percentage of Harrison germplasm Florida paspalum. Seed lots (Generation 0 and 1) used in the study were harvested, cleaned and stored in a controlled environment. Age of seed, stratification (moistened and stored at 38^{0}F for 14 d) and control (no stratification) were arranged in factorial experiment in randomized complete block design with four replications in a germination chamber (86-68°F/8-10 hrs.). In the generation 0 seed lot, there was no response to stratification for seed ages 6, 5, and 4. The control exhibited significantly greater ($P<0.008$) germination percentage in these seed ages (78 vs. 65%). There was not a significant difference ($P>0.40$) in germination percentage for seed treatments in seed ages 2 and 3. A significant ($P<0.02$) response to stratification was observed in Generation 1 seed lot compared to the control (42 vs. 26%) which followed a similar germination trend as Generation 0. This study suggests seed dormancy in recently harvested seed (<3 yr) of Harrison germplasm Florida paspalum can be overcome with stratification and long term storage (>3 yr) in a controlled environment.

Key words: Florida paspalum, Harrison germplasm, seed age, seed germination

Practical Insights into Controlling Undesirable Non-Native Species in Pennsylvania's Native Meadows and CREP Areas

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Summary

I find the most limiting factor to the success of a native restoration project to be the invasion of undesirable species. With proper planning and follow-up maintenance, this can be avoided. The theme of this presentation is developing a practical planting sequence and the use of selective herbicide control measures to create an aggressive native cover that replaces or out competes several invasive species, and lasts until the undesirable species are not competitive. In addition to the combinations discussed here, there are many more invasive species and other desirable native plant combinations that could be used.

Key words: Herbicides, invasives, native plant establishment, weed control

Past Failures

One-time pre-plant weed control measures are not effective in the long run. For example, pre-plant glyphosate applications are generally not effective on Canada thistle [*Cirsium arvense* (L.) Scop.] Crownvetch (*Coronilla varia* L.), or quackgrass [*Elymus repens* (L.) Gould] unless you use several applications along with a crop rotation such as Roundup Ready® soybeans [*Glycine max* (L.) Merr.]. A spring application of glyphosate may even enhance the growth of Canada thistle and crownvetch from deep roots by reducing the competition from shallow-rooted species. However, the use of glyphosate and an annual crop of buckwheat (*Fagopyrum esculentum* Moench) the year prior to planting natives can be key for success the first year of establishment.

Planning

The first step is to establish the objective of your restoration plan by identifying the weeds you need to control as part of that plan. Make some decisions up front as to the invasives that will jeopardize your goals. If you must eliminate crown vetch, white sweetclover (*Melilotus alba* Medikus), and yellow sweetclover [*Melilotus officinalis* (L.) Lam.], typical questions would be:

- Can you live without any legumes or do you want some to remain?
- Are you trying to preserve an endangered species that would be impacted by the use of herbicides?
- Does your application comply with the herbicide label?

Check local labeling and conduct your own test before following my recommendations. Use label research and tests to prevent an alternate invasive species from replacing the current species of concern.

I am going to relate my experience with selective herbicides to control invasive species while re-naturalizing with a sustainable native cover. We have developed several native seed mixes and herbicide treatments that can be used to control some common invasive and non-native weedy species.

Establishment

As a minimum goal on all restoration projects that contain invasive species, I would start control by mowing or clipping the site during the growing season, and applying glyphosate between August and winter. A repeat application of glyphosate the following spring, one week before planting, will further reduce annual and perennial weed competition. The next step is to create a firm seedbed with loose soil that will provide good seed to soil contact. This is done by tilling and rolling or by planting with a no-till drill. In all cases, the native seed should be in the top ¼ in. of firm soil. However, this ideal growing condition will be just as good for the invasive species as it is for your desirable species. Therefore, this is when selective weed control starts. In the first year, clipping just above the desired species is a universal recommendation.

Example 1

If the invasive species you found to be of concern are Canada thistle, crownvetch, Serecia lespedeza [*Lespedeza cuneata* (Dum.-Cours.) G. Don], white sweetclover (*Melilotus alba* Medikus), or spotted knapweed (*Centaurea biebersteinii* DC), you can establish the following diverse native grass and forbs mix and use the chemical control below to help with weed suppression:

Canada Wild Rye (*Elymus canadensis var. canadensis* L.)
or
Silky Wild Rye (*Elymus villosus var villosus* Muhl. ex Willd.)

Big Bluestem (*Andropogon gerardii* Vitman)
Little Bluestem (*Schizachyrium scoparium* Michx. Nash)
Path Rush (*Juncus tenuis* Willd.)
Switchgrass (*Panicum virgatum* L.)
Common Milkweed (*Asclepias syriaca* L.) -or-
Butterfly Milkweed (*Asclepias tuberosa* L)
Virginia Mountain Mint [*Pycnanthemum virginiana* (L.) T. Dur. & B.D. Jackson ex B.L. Robins & Fern]
Culver's Root [*Veronicastrum virginicum* (L.) Farw.]
Tall White Beard Tongue (*Penstemon digitalis* Nutt. ex Sims)
Great St. John's Wort (*Hypericum pyramidatum* Ait.)
St. John's Wort (*Hypericum perforatum* L.)
Eastern Columbine (*Aquilegia canadensis* L.)
Spotted Beebalm (*Monarda punctata* L.) -or-
Wild Bergamot (*Monarda fistulosa* L.)

Chemical Control

Along with a clipping regime following the establishment of the seedlings, a post-emergent treatment of 1/3 to 2/3 pt of Stinger® should be applied between rosette and bud stage of Canada thistle or spotted knapweed. Be aware that this treatment will eliminate desirable and undesirable plants in the *Leguminosae* and *Asteraceae* families. My experience shows that this may require repeated applications for the eradication of these invasive species.

Example 2

If the invasive species of concern are Canada thistle, crownvetch, hairy vetch (*Vicia villosa* Roth), white and yellow sweetclover, *Brassica spp*, including wild radish (*Raphanus raphanistrum* L.), yellow rocket (*Barbarea vulgaris* Ait. f.), garlic mustard [*Alliaria petiolata* (Bieb.) Cavara & Grande], and many other broadleaf weeds, the following mix of grasses and legumes, along with the following chemical control can be used:

Big Bluestem (*Andropogon gerardii* Vitman)
Little Bluestem (*Schizachyrium scoparium* Michx. Nash)
Purple Top [*Tridens flavus* (L.) A.S. Hitchc.]
Nimblewill (*Muhlenbergia schreberi* J.F. Gmel.)
Indiangrass [*Sorghastrum nutans* (L.) Nash]
Showy Tick Trefoil [*Desmodium canadense* (L.) DC.]
American Senna [*Senna hebecarpa* (Fern.) Irwin & Barneby]
Blue Wild Indigo [*Baptisia australis* (L.) R. Br. ex Ait. f.]
Sundial Lupine (*Lupinus perennis* L.)
Partridge Pea [*Chamaecrista fasciculata* (Michx.) Greene]
Round Head Lespedeza (*Lespedeza capitata* Michx.)
Hairy Lespedeza [*Lespedeza hirta* (L.) Hornem.]

Chemical Control

Along with the pre-plant preparation and establishment described previously, a post-emergent application of ½ pt of MCPA® can be sprayed over this mix of natives when weeds are actively growing. Repeated applications will be required to control the most persistent invasive, non-native weeds.

Example 3

If the invasive species of concern are quackgrass, tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire], other cool-season grasses, winter annuals and bi-annuals; such as, *Brassica spp*, *Rumex spp*, wild carrot (*Daucus carota* L.), chickweed [*Stellaria media* (L.) Vill.], teasel (*Dipsacus fullonum* L), burdock (*Articum spp*), and bull thistle [*Cirsium vulgare* (Savi.) Ten.], which can or will re-invade a native restoration mix, you can selectively control those species that have not evolved with fire. The following mix is typical of native species that have evolved through a fire ecology, which can be maintained with selective mechanical and chemical means:

Big Bluestem (*Andropogon gerardii* Vitman)
Little Bluestem (*Schizachyrium scoparium* Michx. Nash)
Indiangrass [*Sorghastrum nutans* (L.) Nash]
Sideoats Grama [*Bouteloua curtipendula* (Michx.) Torr.]
Blue Grama [*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffith]
Purple Top [*Tridens flavus* (L.) A.S. Hitchc.)
Switchgrass (*Panicum virgatum* L.)
Nimblewill (*Muhlenbergia schreberi* J.F. Gmel.)
Common Milkweed (*Asclepias syriaca* L.) -or-
Butterfly Milkweed (*Asclepias tuberosa* L.)
Showy Tick Trefoil [*Desmodium canadense* (L.) DC.]
Round Head Lespedeza (*Lespedeza capitata* Michx.) -or-
Hairy Lespedeza [*Lespedeza hirta* (L.) Hornem.]
Blue Wild Indigo [*Baptisia australis* (L.) R. Br. ex Ait. f.]
Wild Senna [*Senna hebecarpa* (Fern.) Irwin & Barneby] -or-
Maryland Senna [*Senna marilandica* (L.) Link]
Giant Sunflower (*Helianthus giganteus* L.)
Partridge Pea [*Chamaecrista fasciculata* (Michx.) Greene]
Culver's Root [*Veronicastrum virginicum* (L.) Farw.]
Wingstem [*Verbesina alternifolia* (L.) Britt. ex Kearney]
Ox Eye Sunflower [*Heliopsis helianthoides* (L.) Sweet]
Canada Goldenrod (*Solidago canadensis* L.)
Giant Ironweed (*Vernonia gigantea* (Walt.) Trel.)

Chemical Control

To control cool-season species, mowing or burning is advised during the dormant period to remove thatch and debris, before the early spring application of glyphosate. By using glyphosate as a selective herbicide, native grass and forbs species that evolved with a fire ecology are dormant during the early spring. Allow 2 weeks following mowing or burning for the cool-season grasses to recover before applying glyphosate. During this dormant period of warm-season grasses is an opportunity to apply 2 pt of Roundup Original® or GlyStar™ Original as a selective herbicide to control cool-season species actively growing during the early spring. The distinction between warm and cool-season grasses is blurred in hardiness zones 7 and above. Be cautious not to use glyphosate products that contain super active surfactants, and do not add surfactants other than non-ionic surfactant and ammonium sulfate, as they may have soil activity beyond leaf contact.

Example 4

If your species of concern are annual and perennial weed seedlings; such as giant foxtail (*Setaria faberi* Herrm.), johnsongrass [*Sorghum halepense* (L.) Pers.], and Japanese stiltgrass [*Microstegium vimineum* (Trin.) A. Camus], as well as many broadleaf weeds, the following is one of the most reliable diverse native mixes, in conjunction with the mechanical and chemical control listed:

Big Bluestem (*Andropogon gerardii* Vitman)
Little Bluestem (*Schizachyrium scoparium* Michx. Nash)
Indiangrass [*Sorghastrum nutans* (L.) Nash]
Side Oats Grama [*Bouteloua curtipendula* (Michx.) Torr.]
Nimblewill (*Muhlenbergia schreberi* J.F. Gmel.)
Black Eyed Susan (*Rudbeckia hirta* L.)
Lanceleaf Tickseed (*Coreopsis lanceolata* L.)
Showy Tick Trefoil [*Desmodium canadense* (L.) DC.]
Blue Wild Indigo [*Baptisia australis* (L.) R. Br. ex Ait. f.]
Partridge Pea [*Chamaecrista fasciculata* (Michx.) Greene]

Chemical Control

Journey® is one of the best weapons against invasive species in native grass and forbs mixes. This treatment is best used the year following an annual crop or a fall glyphosate treatment and tilling. Journey®, applied at 21.3 oz to 32 oz/ac, can be used in the spring pre-plant to control emerged cool-season grasses and winter annuals. Journey® can also be used to revitalize a native grass and forbs meadow. Start by mowing or burning during the winter, and applying Journey®, at 10.7 fl oz/ac, before the native species begin growth in early spring. **Note:** Journey® does not control crownvetch) or other common legumes.

Conclusion

Natives will not out compete invasive non-natives without human intervention. With the proper planning, this intervention can be minimized. Because natives are slow to emerge and mature, post-establishment review and maintenance, as well as patience, is a critical part of any restoration plan.

Disclaimer

All of the above herbicides are labeled for use on non-crop, CREP or, non-pasture areas, and/or as a spot treatment for invasive species.

This presentation is based on my observations and specific conditions and locations, and is meant to expand one's thinking on methods of control. Herbicides should be applied by qualified personnel. Before applying any herbicide, read all labels and observe worker protection standards.

Traditional Establishment Recommendations for Native Warm-Season Grasses

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Abstract

Over the past 60 years, the USDA, Natural Resources Conservation Service, USDA, Agricultural Research Service, and State Agricultural Experiment Stations have developed establishment technology to restore ecosystems and produce forage and wildlife habitat. In the eastern United States, poor technology transfer, low levels of utilization of the technology by producers and agency and university employees, and employee turnover has resulted in a low level of awareness of traditional establishment technology. The simplest of establishment principles such as seed stratification, seeding dates to overcome stratification, seeding dates, the importance of firm seedbeds, the necessity of drilling, pure live seed (PLS) calculation, drill calibration, seedbed preparation, and weed control have been developed and must be reinforced. The poster will present these principles.

Key words: Seeding dates, seeding method, seeding rate, site preparation

Summary of Recommendations

Site Preparation

Introduced Species Stands – Kill the stand with herbicide while the grass is actively growing (previous summer for warm-season grasses, previous fall for cool-season grasses). Sow seed no-till to avoid exposing dormant seeds to optimum germination conditions.

Row Crops – Practice good weed control the previous growing season to control annual weeds. Sow seed with or without tillage.

Seeding Rate

Sow seed at the standard rates specified in Table 1 or adjust to desired seed densities specified in Table 2. Check spacing with data in Table 3.

Seeding Dates

Sow unstratified seed before the date of last frost in the spring with most species (Table 4). Sow unstratified seed of eastern gamagrass [*Tripsacum* dactyloides(L.) L.] before December 1, stratified seed at normal corn planting time. Sow coastal panicgrass [*Panicum amarum var. amarulum* (A.S. Hitchc.&Chase) P.G. Palmer] before June 1.

Seeding Method

Drill into firm seedbed preferred. Pack after the drilling.

Weed Control

Perennial Introduced Grass Species - Glyphosate or paraquat before seeding or during the winter. Plateau any time recommended on the label.

Annual Species – mow tops after flowering and before seed production, apply 2,4-D and/or dicamba to kill all broadleaf plants, apply Plateau to kill grass and broadleaf weeds and allow native forbs to survive.

Fertilization

Establishment Year - Apply phosphorus and potassium to soil test to produce 100 bushels of corn per acre. Apply nitrogen when a stand is established at 40-50 pounds per acre (mid-year).

Maintenance - Apply phosphorus and potassium to soil test to produce 100 bushels of corn per acre. For forage or biofuel, apply nitrogen at 40-50 pounds per acre (70-80 for eastern gamagrass) as growth begins and 40-50 pounds per acre (70-80 for eastern gamagrass) in the middle of the growing season. For wildlife or erosion control, apply nitrogen at 20-25 pounds per acre as growth begins and 20-25 pounds per acre in the middle of the growing season.

Harvesting

Grazing – Remove half the height growth when the grass is 8-12 inches tall (leave 4-6 inches of stubble).

Hay – Mow when the grass is 24 inches tall and leave a stubble height of 6 inches.

Wildlife Stand Management

Burn every three years. It is best to burn 1/3 of the area every year on a three-year rotation so there are two other areas with different levels of residue in the stand.

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Table 1. Seeding rates of various warm-season grasses (lb of pure live seed per acre).

	Erosion Control/ Forage Production		Wildlife Habitat Development (Calibrate to Rate for 8-Inch Rows)			Example 3-Species Mixture
Species	Drilled in 8-in. rows	Broadcast	Drilled in 16-in. rows	Drilled in 24-in. rows	Drilled in 32-in. rows	Drilled in 8-in. rows
Eastern Gamagrass		N/A	N/A	N/A	8-16 (30" Rows)	
Big Bluestem	8-12	12-18	4-6	3-4	2-3	3-4
Indiangrass	8-12	12-18	4-6	3-4	2-3	3-4
Sideoats Grama	8-12	12-18	4-6	3-4	2-3	
Deertongue	12-16	18-24	6-8	4-5	3-4	
Little Bluestem	8-12	12-18	6-8	4-5	3-4	
Coastal Panicgrass	10-15	15-20	5-8	3-5	2-4	
Switchgrass	6-8	10-12	3-4	2-3	1-2	2-3

Table 2. Seeding rate needed to achieve specific seed densities.

		Seeds per square foot										
Species	Seeds per lb	1	5	10	20	30	40	50	60	70	80	90
		----------------lb seed per acre----------------										
Eastern Gamagrass	6,000	7	14	73								
Big Bluestem	165,000			3	5	8	11	13	16	18	21	24
Indiangrass	175,000			2	5	7	10	12	15	17	20	22
Sideoats Grama	191,000			2	5	7	9	11	14	16	18	21
Deertongue	225,000			2	4	6	8	10	12	14	15	17
Little Bluestem	260,000			2	3	5	7	8	10	12	13	15
Coastal Panicgrass	300,000			1	3	4	6	7	9	10	12	13
Switchgrass	390,000			1	2	3	4	6	7	8	9	10

Table 3. Seed densities at specific row and seed spacings.

Row spacing		Seed spacing in inches (seeds per foot)					
Inches	Feet	0.25(48)	0.50(24)	0.75(16)	1.00(12)	2.00(6)	4.00(3)
		---------------------------seeds per square foot---------------------					
8	0.67	71	35	24	17	9	5
16	1.33	36	18	12	9	5	3
24	2.00	24	12	8	6	3	1.5
30	2.50	19	10	7	5	3	1.5
32	2.67	18	9	6	5	3	1.5
36	3.00	16	8	5	4	2	1
40	3.33	14	7	5	4	2	1
48	4.00	12	6	4	3	1.5	.75

Table 4- Dates of last frost at selected locations (10% chance of frost after each date)

Date	City	Date	City	Date	City
February 1	Ft Lauderdale, FL	April 15	New York, NY	May 15	Bar Harbor, ME
February 15	Fort Pierce, FL		Philadelphia, PA		Hartford, CT
March 1	Orlando, FL		Virginia Beach, VA		Syracuse, NY
March 15	Brunswick, GA		Beaufort, NC		Williamsport, PA
	Jacksonville, FL		Columbia, SC		Lexington, VA
	Mobile, AL		Augusta, GA		Middleboro, KY
	Biloxi, MS		Birmingham, AL		Cleveland, OH
April 1	Manteo, NC		Tupelo, MS		Fort Wayne, IN
	Beaufort, SC		Nashville, TN		Rockford, IL
	Savannah, GA		Evansville, IN		Detroit, MI
	Gainesville, FL	May 1	Boston, MA		Madison, WI
	Montgomery, AL		Harrisburg, PA	June 1	Portland, ME
	Jackson, MS		Williamsburg, VA		Hyannis, MA
	Memphis, TN		Raleigh, NC		Nashua, NH
	Cairo, IL		Greenville, SC		Montpelier, VT
			Kingsport, TN		Elmira, NY
			Wheeling, WV		Erie, PA
			Lexington, KY		Buckhannon, WV
			Columbus, OH		Athens, OH
			Indianapolis, IN		Lansing, MI
			East St. Louis, IL		Green bay, WI

Evaluation of Weed Control During Switchgrass Establishment with Postemergence Herbicides

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Grassy weeds reduce establishment of switchgrass (*Panicum virgatum* L.), so identifying herbicides which can control them postemergence without inhibiting switchgrass growth would be useful. Quinclorac and sulfosulfuron, recently labeled for warm-season grasses grown for CRP and seed production, were evaluated in combination with broadleaf herbicides for both weed control and switchgrass seedling injury. Cave-in-Rock switchgrass was seeded on May 18, 2005 at 12 lb pure live seed/ac with a Tye no-till drill at Rock Springs, PA. Nine herbicide treatments included: quinclorac (0.248 and 0.375 lb ai/ac); sulfosulfuron (0.035 and 0.062 lb ai/ac); quinclorac (0.248 lb ai/ac) tank mixed with the following: dicamba plus diflufenzopyr (0.175 lb ai/ac); metsulfuron (0.011 lb ai/ac); thifensulfuron (0.023 lb ai/ac); atrazine (1.0 lb ai/ac); and halosulfuron (0.031 lb ai/ac). All treatments were applied postemergence on June 24, 2005 when switchgrass was 4 in. tall with three leaves. Weeds present at the time of application included common lambsquarters (*Chenopodium album* L.), redroot pigweed (*Amaranthus retroflexus* var. salicifolius), fall panicum (*Panicum dichotomiflorum* Michx.), witchgrass (*Panicum capillare* L.), and both yellow [*Setaria glauca* (L.) Beauv.] and green foxtail [*Setaria viridis* (L.) Beauv.]. Switchgrass injury was estimated at 1, 2, and 4 weeks after application (WAA) and weed control at 2, 4, and 8 WAA. Weed control and injury were visually estimated on a scale of 0 (no control or injury) to 100 (complete control or plant death) and the following results are based on weed control ratings 8 WAA. Quinclorac at 0.248 lb/ac provided 82% control of the foxtail species, while providing less control of fall panicum and witchgrass (63%), common lambsquarters (50%), and redroot pigweed (50%). Increasing the rate of quinclorac to 0.375 lb/ac did not improve control of either the panicum or foxtail species and slightly increased control of lambsquarters (68%) and pigweed (67%). The addition of dicamba plus diflufenzopyr increased control of lambsquarters (92%) and pigweed (90%), while maintaining grass weed control similar to quinclorac alone. The combination of either metsulfuron or thifensulfuron with quinclorac also increased broadleaf control, but significantly reduced fall panicum and witchgrass control. Halosulfuron, compared to quinclorac, provided similar pigweed control, was less effective on fall panicum and witchgrass, and provided similar control of lambsquarters and foxtail as the 0.248 lb/ac quinclorac rate. Tank mixing atrazine with quinclorac did not improve performance compared to quinclorac alone. Sulfosulfuron applied at 0.035 and 0.062 lb/ac provided 67 and 70% control of fall panicum and witchgrass, 43 and 53% control for foxtail species, 37 and 47% control for pigweed, and 39 and 40% control for lambsquarters, respectively. All herbicide treatments showed slight leaf chlorosis 1 WAA, which disappeared by 4 WAA. First year results indicate that quinclorac alone at both the 0.248 and 0.375 lb/ac rates adequately controled foxtails, while maintaining crop safety.

The addition of a growth regulator herbicide increased the spectrum of control by providing additional broadleaf weed control.

Key words: Chemical weed control, herbicide injury, Paramount, quinclorac

Comparison of Imazapic and Clethodim to Selectively Remove Tall Fescue from Remnant Native Grasslands in Kentucky

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Native grasslands are one of the most endangered ecosystems in North America. Exotic, invasive plants are a serious threat to the fitness of isolated remnant native grasslands. Tall fescue (*Lolium arundinaceum* (Schreb.) S.J. Darbyshire) is a non-native, invasive cool-season grass that occurs throughout Kentucky and the eastern United States. Its widespread distribution and invasive habits threatens the integrity of native grassland communities. The objective of this study was to determine the efficacy of using a graminicide (clethodim) with or without prescribed fire applied at different times on actively growing tall fescue to selectively remove this species from native grasslands while protecting the existing native plant diversity. Clethodim was applied at 0.21 lb ai/acre in early and mid-April 2001 in 0.25-acre plots at four locations in a completely randomized design experiment. This treatment was compared to a known positive tall fescue control (imazapic at 0.18 lb ai/acre) and an untreated check. Two of the treatment locations were burned prior to herbicide application. Clethodim reduced tall fescue cover to 9% or less at three of the treatment locations, and it did not differ ($P > 0.05$) from the imazapic treated plots. Burning had no effect ($P > 0.05$) on tall fescue or native grass cover. Percent cover of native grasses was not different among herbicide treated plots ($P > 0.05$). Burning in combination with herbicide treatments had no effect ($P > 0.05$) on percent bare ground, number of forbs or total number plant species/ft^2. However, percent total vegetation, percent forbs, and vegetation height were higher ($P < 0.05$) in burned plots. Additionally, there was no difference in tall fescue or native grass canopy cover due to timing of herbicide application. This study demonstrates that clethodim can be used as effectively as imazapic to selectively remove tall fescue from degraded native grasslands in Kentucky without eliminating the native warm-season grass community. Furthermore, burning prior to herbicide application did not improve the efficacy these herbicides to kill tall fescue, but it did facilitate the release of forbs.

Key words: Clethodim, fire, Imazapic, invasive grass

Compatibility of a Mixture of Canada, Virginia and Riverbank Wildrye Seeded with Seven Individual Species of Native and Introduced Cool-Season Grasses

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There is interest in the utilization of native cool-season grasses for conservation plantings for erosion control, riparian buffers and wildlife habitat. Native cool-season grasses typically are easier and quicker to establish than native warm-season grasses and may be able to compete with the prevalent introduced cool-season grasses and weeds in the Northeast. We evaluated a 1:1:1 mixture of Canada wildrye (*Elymus canadensis* L.), Virginia wildrye (*Elymus virginicus* L.) and river bank wildrye (*Elymus riparius* Wieg.) in combination with native grasses: fringed brome (*Bromus ciliatus* L.), fowl bluegrass (*Poa palustris* L.), rough bentgrass (*Agrostis scabra* Willd.), upland bentgrass [*Agrostis perennans* (Walt.) Tuckerman] and introduced conservation grasses: red fescue (*Festuca rubra* L.), tall fescue cv. Falcon II [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire], and red top (*Agrostis gigantea* Roth). The companion species were seeded with the wildrye mix at three different seeding rates per species based on seed size and weight.

On 8/17/04 the wildrye mixture was seeded at 20 lbs/ac into a conventionally prepared cultipacked seed bed. The companion species were hand seeded over the wildrye in 20 x 10 ft plots in a completely randomized block design with four replications. The fringed bromegrass, tall fescue and red fescue were seeded at 3, 6 and 9 lb/ac; the rough bentgrass, upland bentgrass and red top were seeded at 0.25, 0.5, and 0.75 lb/ac and the fowl bluegrass was seeded at 0.5, 1 and 2 lb/ac. The field was cultipacked again after planting. The seedings established and overwintered well. On 8/17/05 and 6/15/06 two 2 x 2 ft biomass samples were cut from each plot, the wildrye mixture and the companion species were separated and dry matter was determined for each. Visual ratings were made on each of the plots for density of weeds, wildrye mixture and companion species.

Based on 2005 data and visual evaluations made in 2006 the fringed bromegrass was the least competitive of the species on the wildrye at even the 9 lb/ac rate. The control, consisting of the wildrye mix alone, and the fringed bromegrass/wildrye mix at all of the 3 fringed bromegrass seeding rates had significantly higher wildrye biomass than the other mixtures. The fowl bluegrass mixture had the next highest wildrye biomass content at the 0.5 lb/ac rate. In 2005 the wildrye dry matter biomass for the control, fringed bromegrass and fowl bluegrass were 3,962, 2,907, and 1,439 lb/ac respectively. There were no statistical differences between wildrye biomass due to the effects of the seeding rates within any of the companion species treatments. All of the *Agrostis* species treatents were not compatible with the wildrye even at the 0.25 lb/ac rate having lower wildrye biomass levels (432 lb/ac) compared to the control. The *Agrostis* species were also effective at reducing weed encroachment. The tall fescue and red fescue were competitive on the wildrye even at the 3 lb/ac rate with the tall fescue being slightly more competitive. The tall fescue had fewer

weeds than the red fescue. The average wildrye biomass for both fescue mixtures averaged over all of the seeding rates was 480 lb/ac.

Key words: Cool-season, establishment, mixtures, wildrye

Yield of Eastern Gamagrass with and without Big Bluestem and Switchgrass

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Abstract

A study was conducted to increase biomass and deter weed encroachment in establishing eastern gamagrass [*Tripsacum dactyloides* (L.) L.] forage planting. Two species mixtures of eastern gamagrass grown on both 15- and 30-inch row spacings with either switchgrass (*Panicum virgatum* L.) or big bluestem (*Andropogon gerardii* Vitman) were compared to eastern gamagrass alone. Biomass measurements were conducted at the first cutting date on the third (2005) and fourth (2006) year after establishment. Eastern gamagrass first cutting yields were reduced when grown with the switchgrass or big bluestem in 2005 and 2006. The switchgrass and big bluestem filled in between and within gamagrass rows and in areas with poor gamagrass population increasing overall yields. Weed encroachment was reduced by the utilization of the two species mixes. Forage quality was not adversely affected with the mixtures.

Key words: Big bluestem, biomass, eastern gamagrass, forage quality,

Introduction

Eastern gamagrass is one of the most palatable and nutritious of the warm-season grasses and can be used for hay and pasture. It is typically planted with a corn planter due to its seeding depth requirement. In some instances the gamagrass is double planted to achieve a 15-inch row spacing. In the Northeast these row spacings result in late canopy closure which reduces the optimum capture of sunlight for the crop and allows weeds to become established competing for moisture and sunlight. In some instances due to seed quality, expense and handling requirements a full stand of eastern gamagrass may not be obtained. The use of mixed plantings of big bluestem and switchgrass may help fill in between and within the rows of the eastern gamagrass increasing yields and helping to reduce weed establishment. This study was set up to monitor the competition between switchgrass and big bluestem on eastern gamagrass and to observe if the stand composition will be maintained or will be favored by a particular species.

Materials and Methods

The plots were located on a farm in Clarion County Pennsylvania near the town of Shippenville (N41.29 lat. W79.46 long.) at an elevation of 1480 ft on a Cookport channery silt loam soil with a 2 – 3% grade. Prior to amendment, soil test results from the Pennsylvania State University Soil Testing Laboratory indicated the soil pH was 5.8 with optimum phosphorus (16 ppm) and potassium (50 ppm) levels. The field was in hay for over three years prior to the project. In 2002 the field was sprayed with glyphosate in the spring, and then chisel plowed to 12 – 14 inches, disked, mechanically summer fallowed, and then planted to oats (*Avena sativa* L.) in late Summer.

In the Spring of 2003 the field was chisel plowed 12 – 14 inch deep, disked and planted to gamagrass with a corn planter at a 1.5 inch depth. The field was cultipacked prior to seeding switchgrass and big bluestem. On 6/1/03 one half of the field (50 ft) was planted to gamagrass in 30-inch rows, the other half was planted in 15-inch rows after recalibrating and double planting. Perpendicular to the gamagrass rows, 18 ft. wide switchgrass and big bluestem treatments were established with a Truax drill across both row spacings by drilling big bluestem in one, and switchgrass in another and leaving an unseeded strip as a control. The resulting 18 x 50 ft plots were replicated four times. The varieties used were 'Pete' eastern gamagrass, 'Cave-In-Rock' switchgrass and 'Niagara' big bluestem. Eastern gamagrass was planted after a 12-week stratification period at a 7 lb/ac bulk rate, the seed test indicated a 48% germination rate. Switchgrass and big bluestem treatments were planted with 4 and 5 lbs/ac bulk seed, respectively. No fertilizer was applied the establishment year. High magnesium lime was applied at 4,500 lbs/ac on 6/27/03. The first year the field was sprayed with 2,4-D in late summer for broadleaf weed control and clipped to 6 inches. There was good establishment of all species. On 4/21/04 of the second year 350 lbs/ac of 10-24-24 fertilizer was applied. There was no harvest or clipping in 2004. On 4/15/05 of the first sampling year a dormant spray of glyphosate was applied at 1 qt/ac.

On 6/23/05 biomass samples were collected by cutting two 2 x 2 ft squares of switchgrass and big bluestem from each of the switchgrass/gamagrass and big bluestem/gamagrass combination plots. The gamagrass samples were collected from 10 ft of row in the gamagrass 30-inch row treatments and a 5 x 5 ft area for the 15-inch gamagrass row treatments for both the combination and gamagrass control plots. The entire harvested sample was dried in a force air drying oven for dry matter determination. The number of gamagrass plants that made up each sample was recorded. The plots were cut again on 6/20/06 as in 2005 with the addition of plots of big bluestem and switchgrass cut in areas without gamagrass.

An unreplicated forage quality sample for each of the species was analyzed at the Dairy One Forage Testing Laboratory in Ithaca, NY for 2005. The indicators measured were % crude protein (CP), % neutral detergent fiber (NDF), % acid detergent fiber (ADF), % Lignin, % *in vitro* total digestibility for both dry matter (DM) and NDF.

Results and Discussion

In 2005 there was a trend toward increased first cutting gamagrass yields from the plots which were in 15-inch rows (1.33 t/ac) compared to the 30-in rows (0.89 t/ac). Although the drill was recalibrated to maintain the same gamagrass population for the different row spacing treatments. There were on average more plants cut in the same 25 ft^2 area for the 15-inch row plots (13.3) compared to 10.8 plants for the 30-inch row plots. This resulted in the increase yield for the 15-inch row spacing over the 30-inch row spacing in 2005. There was a trend toward lower gamagrass yields from the plots with switchgrass and big bluestem with average yields of 0.62 t/ac compared to gamagrass monocultures at the two row spacings averaging 1.11 t/ac. Switchgrass had the highest yield even when grown with the gamagrass with an average across both gamagrass row spacings of 1.73 t/ac compared to 0.96 t/ac for big bluestem. This could be due to the increased plant density during the initial establishment of the switchgrass compared to the gamagrass. This may be offset in later years if the individual gamagrass plants continue to increase in size and fill in as expected. The 2005 yield data are summarized in Table 1. Although the biomass is displayed in tons

per acre the yields were obtained in portions of the plots with a solid stand of gamagrass and the companion species were obtained in areas directly adjacent to those areas where the gamagrass was cut. This was done to get an indication of the competitive effects of the companion species on the gamagrass in areas with good gamagrass establishment. Therefore the biomass yields are not actual measurements of the overall yield but of the potential yield in areas of good gamagrass establishment.

The average monthly precipitation for the region in 2005 for the months March through June was 4.25 inches below the normal of 15.6 inches. The average monthly temperature for the region in May was 50.8 °F which was 5.0 °F below average. In June the average monthly temperature was 67.7 °F which was 3.4 °F above average.

The unreplicated forage quality sample was taken in 2005 for each of the species to get an indication of the effect that stage of maturity has on forage quality at the time of harvest. Eastern gamagrass was at the early inflorescence stage and big bluestem and switchgrass were still at the vegetative stage. There was very little difference in forage quality between the species (Table 3.), indicating the forage could be harvested at this stage without big bluestem and switchgrass negatively impacting forage quality. There is an indication from these lab results, the stage of growth of the gamagrass cutting and data from other forage analysis studies, that an earlier harvest, at the boot stage may be expected to improve forage quality of the gamagrass over the other two species. Lab results from a forage quality study in New York (Salon and Cherney 1999) showed eastern gamagrass crude protein of 16.3 % and *in vitro* true digestibility of 79.8 % when cut at the early boot stage. The earlier cutting date would also result in lower yields.

In 2006 (Table 2) there was no significant difference in first cutting gamagrass yields between the 15- and 30-inch gamagrass monoculture row spacing treatments with yields of 1.18 and 1.28 t/ac respectively. The first cutting gamagrass monoculture yield from the 30-inch row spacing increased from 0.89 t/ac in 2005 to 1.28 t/ac in 2006. The plant number was difficult to count due to merging and increased growth of the crowns. There was a significant reduction in yield from the gamagrass component of the switchgrass and big bluestem mixtures with an average of 0.69t/ac compared with an average yield of the gamagrass without the big bluestem and switchgrass of 1.23 t/ac. In 2006 there was a reduction in switchgrass yields compared to 2005. In 2006 when sampled in areas adjacent to the gamagrass at both row spacings the switchgrass averaged 0.78 t/ac. When sampled in areas without gamagrass there were yields of 1.40 t/ac. In 2005 the switchgrass average yield adjacent to the gamagrass at both row spacings was 1.73 t/ac. A reduced amount of perennial weeds (asters (*Aster* spp.), goldenrod (*Solidago* spp.) and milkweed (*Asclepias* spp.)) were observed in the mixed stands compared to the gamagrass monoculture at both gamagrass row spacings (no data presented).

The average monthly precipitation for the region in 2006 for the months March through June was 0.6 inches below normal. The average monthly temperature for the region in May was 56.0 °F which was 0.2 °F degrees above average. In June the average monthly temperature was 64.3°F which was average for the month.

Literature Cited

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Table 1. Biomass of first cutting of eastern gamagrass at 15- and 30-inch row spacings with and without switchgrass and big bluestem in 2005[1].

Species or mixture[2]	Gamagrass row spacing (in.)	Species	Tons/ac[3]
Gamagrass	15	Gamagrass	1.33 abc
Gamagrass	30	Gamagrass	0.89 bc
Gamagrass/Switchgrass	15	Gamagrass	0.79 c
Gamagrass/Switchgrass	30	Gamagrass	0.50 c
Gamagrass/Big bluestem	15	Gamagrass	0.57 c
Gamagrass/Big bluestem	30	Gamagrass	0.59 c
Switchgrass/Gamagrass	15	Switchgrass	1.77 a
Switchgrass/Gamagrass	30	Switchgrass	1.69 ab
Big bluestem/Gamagrass	15	Big bluestem	0.99 abc
Big bluestem/Gamagrass	30	Big bluestem	0.93 bc
$LSD_{.05}$			0.85

[1]Biomass for one cutting conducted on 6/23/05.
[2]The order of the species indicates which species is being measured for biomass.
[3]Values with different letters are significantly different by LSD Test at 0.05 level of probability.

Table 2. Biomass of first cutting of eastern gamagrass, at 15- and 30-inch row spacings with and without switchgrass and big bluestem in 2006[1].

Species or mixture[2]	Gamagrass row spacing (in.)	Species	Tons/ac[3]
Gamagrass	15	Gamagrass	1.18 ab
Gamagrass	30	Gamagrass	1.28 a
Gamagrass/Switchgrass	15	Gamagrass	0.76 cd
Gamagrass/Switchgrass	30	Gamagrass	0.50 d
Gamagrass/Big bluestem	15	Gamagrass	0.73 cd
Gamagrass/Big bluestem	30	Gamagrass	0.77 cd
Switchgrass/Gamagrass	15	Switchgrass	0.91 bc
Switchgrass/Gamagrass	30	Switchgrass	0.66 cd
Big bluestem/Gamagrass	15	Big bluestem	0.89 c
Big bluestem/Gamagrass	30	Big bluestem	0.76 cd
$LSD_{.05}$			0.27

[1]Biomass for one cutting conducted on 6/20/06
[2]The order of the species indicates which species is being measured for biomass.
[3]Values with different letters are significantly different by LSD Test at 0.05 level of probability.

Table 3. Forage quality[1] of eastern gamagrass, switchgrass, and big bluestem harvested on 6/23/05.

	%CP	%ADF	%NDF	%Lig.	%DM IVTD	%NDF IVTD
Gamagrass	13.2	36.7	69.4	4.8	78	70
Switchgrass	13.3	33.7	63.8	3.5	82	71
Big bluestem	14.5	35.5	67.2	6.1	79	69

[1] % crude protein (CP), % acid detergent fiber (ADF), % neutral detergent fiber (NDF), % Lignin (Lig.), % *invitro* total digestibility (IVTD both dry matter (DM) and NDF.

Corn Seeding Rate Effects on Eastern Gamagrass Establishment

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Abstract

Eastern gamagrass [*Tripsacum dactyloides* (L.) L.] is a warm-season perennial bunch grass that could provide high quality forage for grazing or haying during the summer months. However, establishment can be challenging. In addition to seed dormancy, weed control during establishment can be difficult. Although eastern gamagrass is tolerant of many corn herbicides, no preemergence herbicides are labeled for use at this time. Seeding eastern gamagrass with corn may provide an opportunity to use preemergent corn herbicides during the establishment period and at the same time provide usable forage in the establishment year. The objective of this study was to determine the effect of corn (*Zea mays* L.) seeding rates on corn yield and establishment of eastern gamagrass planted in narrow rows. In mid-April, 2005, a mixture of corn and eastern gamagrass was planted using a cultipack type seeder near Blackstone, VA. Treatments consisted of 10 lb pure live seed (PLS) ac^{-1} of eastern gamagrass + 0, 10,000, 20,000, 30,000, 40,000, and 50,000 seeds ac^{-1} of corn. Preemergent corn herbicides were applied immediately after seeding. Corn was harvested at the late tassel stage (92 days after planting). Corn yield ranged from 3800 to 6600 lb ac^{-1} with the highest yield occurring at 40,000 seeds ac^{-1}. Corn seeding rate had no effect on stand density of eastern gamagrass ($P = 0.85$). Averaged across corn seeding rates, gamagrass seedlings were present at a density of 0.76 plants ft^{-2} in the establishment year. One year after seeding stand densities had increased to 1.38 plants ft^{-2}.

Key words: Corn, eastern gamagrass, establishment

Introduction

Eastern gamagrass is a warm-season perennial bunch grass with good potential for high quality summer grazing, harvested forage (hay and silage), and conservation systems (Springer and Dewald, 2004). It is a relative of present day corn and is native to the Midwestern and eastern United States (Hitchcock, 1935). Unfortunately overgrazing has resulted in the loss of most native eastern gamagrass stands (Rechenthin, 1951). High productivity and nutritive value relative to other warm-season grasses has resulted in a renewed interest in this species. Steers grazing eastern gamagrass have shown average daily gains in the range of 1.75 lb/day (Burns et al., 1992; Owsley et al., 1999).

However, establishment can be challenging. In addition to seed dormancy imposed by its morphology and possibly physiological factors (Milby and Johnson, 1989; Anderson, 1985), weed control during establishment can be difficult. Although eastern gamagrass is tolerant of many corn herbicides, at the present time no preemergence herbicides are labeled for use with this species (Springer and Dewald, 2004). Seeding eastern gamagrass with a corn nurse crop may provide the opportunity to utilize preemergent corn herbicides during the establishment period and at the same time provide usable forage in the establishment year.

The objective of this experiment was to determine the effect of corn seeding rates on corn yield and establishment of eastern gamagrass planted in narrow rows.

Methods

This experiment was conducted at the Southern Piedmont Agriculture Research and Extension Center located near Blackstone, VA (37°5'4" N 77°57'51" W). The soil type was a Helena sandy loam (Fine, mixed, semiactive, thermic Aquic Hapludults). Initial soil pH was 5.8 and P and K were in the high and medium range, respectively. A conventional seedbed was prepared by plowing, disking and field cultivating and 100 lb ac^{-1} of N, P_2O_5 and K_2O were incorporated prior to seeding. Plots were seeded in 6 in. rows using a cultipack type seeder (Carter Manufacturing Co., Inc., Brookston, IN) on April 14, 2005. Immediately after seeding, Atrazine 4L (2-chloro-4-ethylamino-6-isopropylamino-s-triazine) and Dual II Magnum (s-metolachlor) were applied at 1.00 and 0.95 lb AI ac^{-1}, respectively.

The experimental design was a randomized complete block with 4 replications. Plot size was 6 x 20 ft. Treatments consisted of 10 lb PLS ac^{-1} of eastern gamagrass + 0, 10,000, 20,000, 30,000, 40,000, and 50,000 seeds ac^{-1} of corn. 'Pete' eastern gamagrass that had been stratified using the proprietary GERMTEC seeded treatment process (Gamagrass Seed Company, Falls City, NE) and 'Amazing Graze 112' grazing type corn (Baldridge Hybrids, Cherry Fork, OH) were used in this experiment. Corn and eastern gamagrass were mixed prior to seeding.

Corn was harvest by hand from the entire plot area on July 15, 2005. A subsample of corn plants from each plot was taken for dry matter and nutritive value determinations. Immediately following corn harvest, stand density for each plot was assessed on a weekly basis until September by counting eastern gamagrass plants in a 1 ft^2 quadrat at six randomly determined locations within each plot.

Corn yield data were analyzed using the general linear model procedure (SAS Institute, Cary, NC). Means were separated using Fisher's protected least significant difference. Stand count data were analyzed using repeated measures procedure (SAS Institute, Cary, NC). Standard errors for the stand count data were calculated using the standard error option for the least square means (SAS Institute, Cary, NC).

Results and Discussion

Rainfall for the period of January to September 2005 was almost 13 in. below the 30-year average of 35 in. During the critical establishment period (April to June) rainfall was approximately one-half of the 30-year average. Although total rainfall was below average during the establishment period, it was well distributed with not more than approximately 1 in. of rain occurring in any single rainfall event. Average daily temperatures were approximately 2 to 3°F above normal for all months during the establishment period with the exception of May.

<u>Corn Yield</u>

Corn plots were harvested when they had reached the late tassel stage (92 days after planting). Whole plant corn yield ranged between 3800 and 6600 lb ac^{-1} and increased with corn seeding rate (Fig. 1). The highest yield occurred at 40,000 kernels ac^{-1}. Other studies conducted at the Southern Piedmont AREC have shown that corn yield was maximized at seeding rates of 60,000 kernels ac^{-1} (data not published). The difference observed between

current and past studies may be due to the lower than normal rainfall in 2005. Assuming a 75% utilization rate, the corn produced in this study could provide approximately 150 to 180 grazing days ac^{-1} during the establishment year. Based on hay valued at \$60 ton^{-1}, this grazing would be worth approximately \$200 ac^{-1}.

Eastern Gamagrass Stand Density

A seeding rate x time interaction was not observed for stand density (P = 0.26). Therefore, the main effects of seeding rate and time are discussed. Seeding rate had no effect on stand density of eastern gamagrass (P = 0.85). This finding is important because it indicates that corn can be planted at densities that will optimize yield in the establishment year, without adversely impacting eastern gamagrass establishment. Averaged across seeding rates, eastern gamagrass seedlings were present in the plot areas at densities of 0.76 plants ft^{-2} (Fig. 2). Since individual eastern gamagrass plants can reach diameters of 3 to 4 ft, stand densities of 1 plant $yard^{-2}$ are commonly accepted as adequate (Roberts and Kallenbach, 1999). Based on this observation, densities observed in the current study are considered exceptional for the seeding year.

Early summer stand counts indicated that around 0.75 plants ft^{-2} were present (Fig. 3). The final two stand counts in late summer (141 and 148 days after planting) indicated a decrease in stand density (Fig. 3). The lower stand densities observed for these dates may be due to counting error that occurred due to a change in the technician performing the counts. In addition, increased weed pressure late in the season may have made accurate stand counts more difficult to achieve. A stand count made the following spring (391 days after planting) indicated that stand densities had increased to 1.38 plants ft^{-2}. This increase may have been due to dormant eastern gamagrass seed germinating after being naturally stratified during the winter months (Mueller et al., 2000). Decreased weed pressure at this date may have also facilitated a more accurate stand count.

Weed Pressure in Plots

The combination of preemergence herbicides and shading from the corn resulted in adequate early season weed control (field observation). After the corn was harvested in July, weed pressure from summer annual grasses (*Digitaria* Haller and *Setaria* P. Beauv. species) and common bermudagrass [*Cynodon dactylon* (L.) Pers.] increased. However, by this time eastern gamagrass seedlings had begun to tiller and appeared to be able to withstand the increased competition from these species (Fig. 3). The following spring, the predominant weed in these plots was common bermudagrass. No herbicides are available to control this perennial warm-season grass in eastern gamagrass. In addition, no temporal opportunities for control using a non-selective herbicide exist since eastern gamagrass initiates growth earlier in spring compared with the bermudagrass. Perhaps the best opportunity for controlling common bermudagrass in eastern gamagrass is cultural. Managing new stands to favor the tall growing eastern gamagrass may help to control the lower growing bermudagrass through shading.

Conclusions

Eastern gamagrass could supply high quality summer grazing for livestock in the mid-Atlanitc region of the United States. However, weed control during establishment can be difficult. Data from this study indicates that planting a mixture of eastern gamagrass and corn

in narrow rows and utilizing preemergent corn herbicides resulted in excellent stands one-year after planting. These initial results need to be repeated.

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Figure 1. Corn yield as impacted by corn seeding rate.

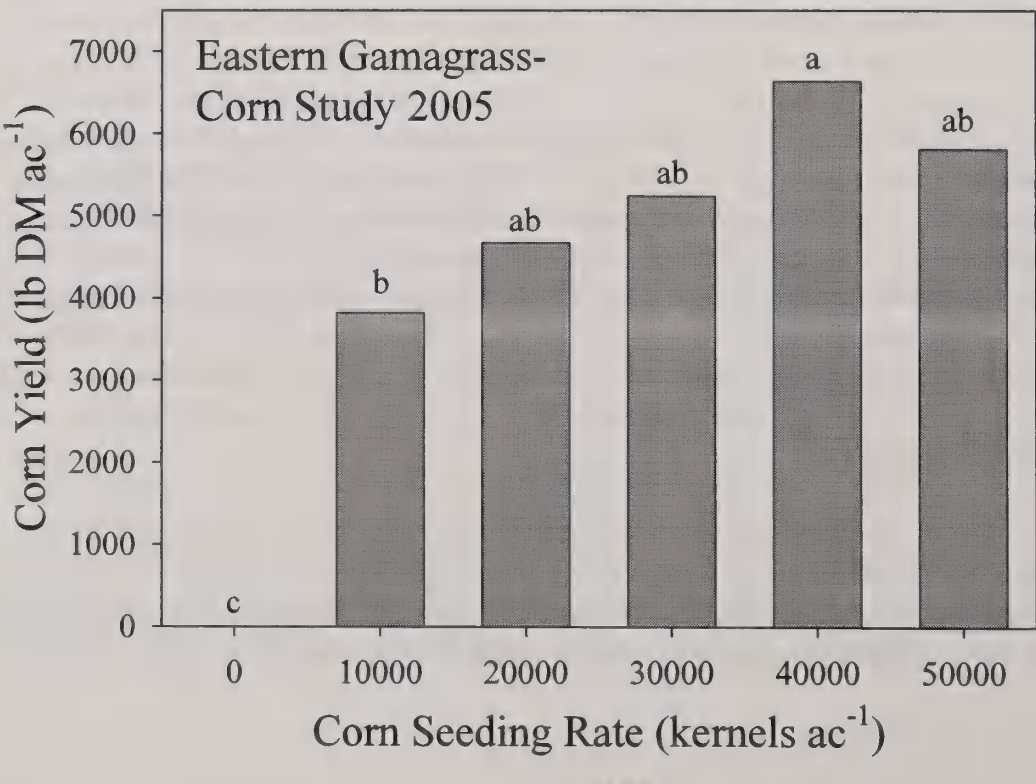


Figure 2. Eastern gamagrass stand density as impacted by corn seeding rate.

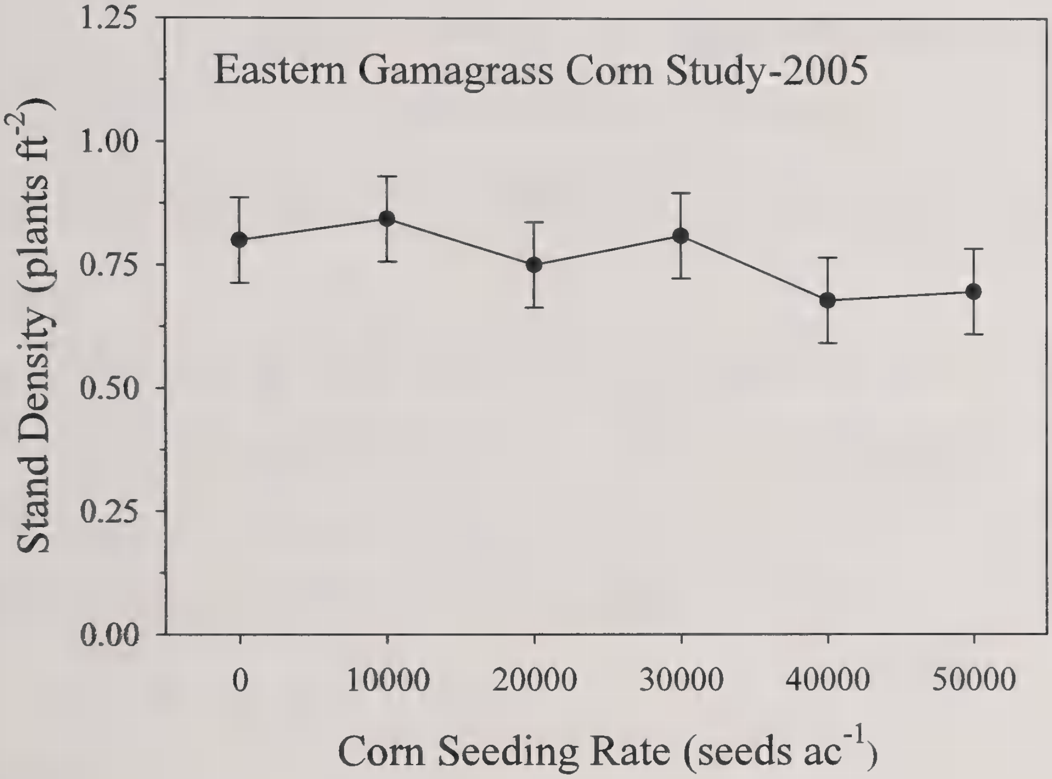
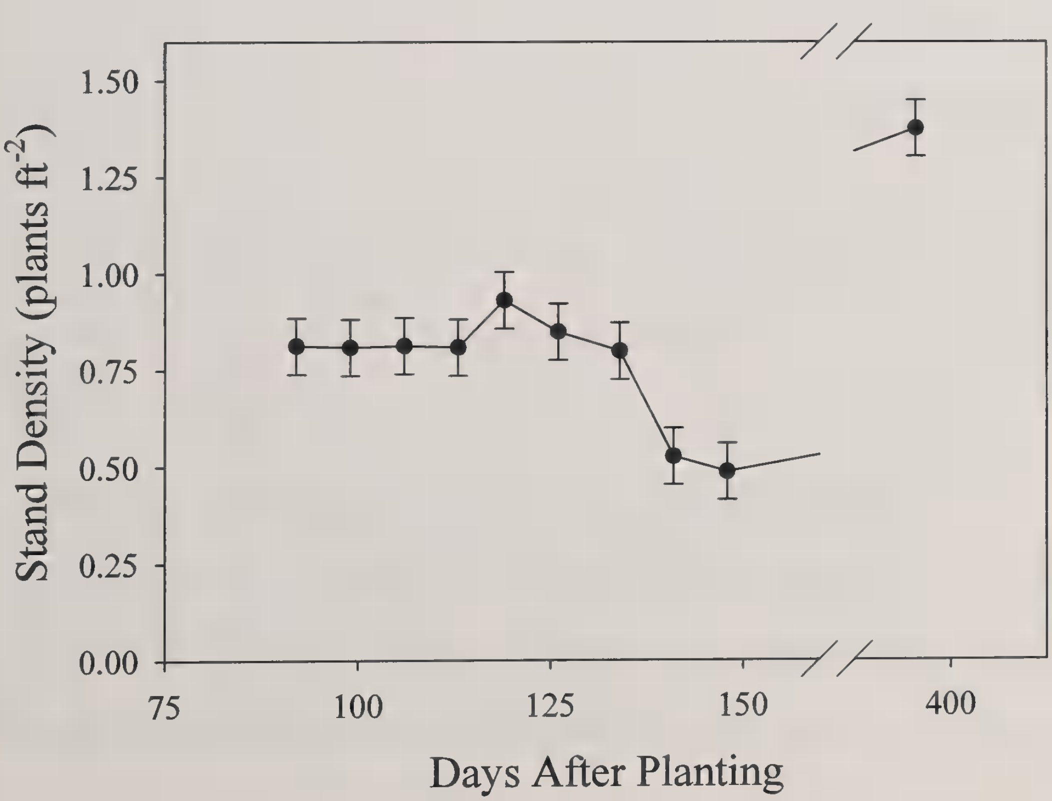


Figure 3. Eastern gamagrass stand density as impacted by time.
9



Invasive Species

Invasive Grass Species at Fort Polk, Louisiana

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Abstract

The invasive plant list at Fort Polk, Louisiana numbers 76 taxa with 27 graminoids including 17 grasses (*Poaceae*) and 10 sedges (*Cyperaceae*). The two worst invasives are Chinese Tallow Tree [*Triadica sebifera* (L.) Small] and Chinese Privet (*Ligustrum sinense* Lour.). The worst graminoid at present is weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees] but both species of *Imperata* [*Imperata brasiliensis* Trin. and *Imperata cylindria* (L.) Beauv.] were recently discovered in the Fort Polk area. Other note-able documented invasive grasses include Johnson grass [*Sorghum halepense* (L.) Pers.], vasey grass (*Paspalum urvillei* Steud.), and itch grass [*Rottboellia cochinchinensis* (Lour.) W.D. Clayton].

Key words: Fort Polk, grass, invasive

Background

Fort Polk is located in west central Louisiana and is divided into two major portions with the larger one encompassing an area of about 150,700 acres (main post) and the smaller one about 46,200 acres (Peason Ridge). The main post and the southern portion of Peason Ridge are in Vernon Parish. The northwest portion of Peason Ridge is in Sabine Parish and the extreme northeast corner of Peason Ridge is in Natchitoches Parish. The major vegetation type is longleaf pine forest but also includes: sandy woodlands, mixed pine-hardwoods, savannahs, pine flatwoods, baygalls, pitcher-plant bogs, upland riparian forests, clay riparian forests, calcareous prairies, Fleming calcareous forests, sandstone glades, swamps, and open water. The vegetation developed in disturbed areas constitutes an additional vegetation type on Fort Polk. The flora consists of 1359 taxa in 145 families (Johnson et al 1993; Allen and Thames 2004). The two families with the most taxa are the *Asteraceae* (Sunflower Family) and the *Poaceae* (Grass Family), both with 174 taxa. The next two largest families are the *Cyperaceae* (Sedge Family) with 112 taxa and the *Fabaceae* (Bean Family) with 91 taxa.

Methods

The authors have been involved in a number of botanical surveys and reports on the Fort Polk Flora and vegetation; much of the information on invasive species is derived from these reports (Wagner et al 2004). Additional invasive species information comes from personal observations by the authors and other Fort Polk employees and contractors. The senior author has worked with grasses (*Poaceae*) in the Gulf Coast area since 1970 (Allen et al 2004). As part of Fort Polk long range management, a list of invasive species and management recommendations are being developed for each. The location and extent of

some invasive species on Fort Polk have been located and mapped by GPS and additional records are being added as new locations and/or new species are found and old locations are re-visited.

Results

The current working list of invasive species for Fort Polk includes 76 taxa (Table 1). The list is organized into graminoids and non-graminoids with the taxa arranged alphabetical by family, then genus. The current list includes 27 graminoids (17 grasses and 10 sedges). All taxa have been identified on Fort Polk except for those marked with an asterisk (*) which identifies taxa in the vicinity with the potential for spreading onto the base. The native or non-native status of these taxa is taken from the on-line Plants Database (USDA, NRCS 2006). The invasive or not invasive decisions on Fort Polk for all taxa are made by the authors and other Fort Polk personnel.

Discussion

Currently, the two worst invasive plant species at Fort Polk are Chinese tallow tree and Chinese privet (Table 2). These two plants are wide spread across the base and locally abundant in some areas, especially in the cantonment area. The worst invasive graminoid is weeping lovegrass as it is spreading at a fairly rapid rate in some areas (Table 1). Other graminoid species of concern include Johnsongrass, vaseygrass, and itchgrass. Species of wet disturbed areas such as torpedo grass (*Panicum repens* L.) and many of the sedges are not common on Fort Polk as the wet areas remain relatively disturbance free. Bahiagrass (*Paspalum notatum Flueggé var. saurae* Parodi) is widely used in erosion control but disappears from the landscape as areas return to the native species makeup; natural succession seems to eliminate these and other introduced species (Allen and Thames 2006). The potential for the spread of Brazilian Satintail (*Imperata brasiliensis* Trin.) and Cogongrass [*Imperata cylindria* (L.) Beauv.] is great as both species were recently discovered in west central Louisiana. If either or both of these species move onto Fort Polk, the invasive species problems will increase tremendously.

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Table 1. List of invasive graminoid (grass and sedge) taxa from Fort Polk, Louisiana.

Taxon	Common Name	Family
Cyperus acuminatus Torr. & Hook. ex Torr.	tapertip flatsedge	Cyperaceae
Cyperus compressus L.	poorland flatsedge	Cyperaceae
*Cyperus difformis**	variable flatsedge	Cyperaceae
Cyperus erythrorhizos Muhl.	redroot flatsedge	Cyperaceae
Cyperus esculentus L.	yellow nutsedge	Cyperaceae
Cyperus haspan L.	haspan flatsedge	Cyperaceae
Cyperus iria L.	ricefield flatsedge	Cyperaceae
Cyperus odoratus L.	fragrant flatsedge	Cyperaceae
Cyperus rotundus L.	Nutgrass	Cyperaceae
Cyperus strigosus L.	strawcolored flatsedge	Cyperaceae
Arundo donax L.	giant reed	Poaceae
Chloris canterai Arech.*	Paraguayan windmill grass	Poaceae
Cortaderia selloana (J.A. & J.H. Schultes) Aschers. & Graebn.	Uruguayan pampas grass	Poaceae
Eragrostis curvula (Schrad.) Nees	weeping lovegrass	Poaceae
Imperata brasiliensis Trin.*	Brazilian satintail	Poaceae
Imperata cylindrica (L.) Beauv.*	Cogongrass	Poaceae
Microstegium vimineum (Trin.) A. Camus*	Japanese stiltgrass	Poaceae
Panicum repens L.*	torpedo grass	Poaceae
Paspalum dilatatum Poir.	Dallisgrass	Poaceae
Paspalum notatum Flueggé var. saurae Parodi	Bahia Grass	Poaceae
Paspalum urvillei Steud.	Vasey's grass	Poaceae
Phyllostachys aurea Carr. ex A.& C. Rivière	golden bamboo	Poaceae
Rottboellia cochinchinensis (Lour.) W.D. Clayton	Itchgrass	Poaceae
Sacciolepis indica (L.) Chase	Glenwoodgrass	Poaceae
Sorghum bicolor (L.) Moench	Sorghum	Poaceae
Sorghum halepense (L.) Pers.	Johnsongrass	Poaceae
Sporobolus indicus (L.) R. Br.	smut grass	Poaceae

* In the vicinity but not yet documented from Fort Polk

Table 2. List of invasive non-graminoid taxa from Fort Polk, Louisiana.

Taxon	Common Name	Family
Alternanthera philoxeroides (Mart.) Griseb.	alligatorweed	Amaranthaceae
Vinca major L.	bigleaf periwinkle	Apocynaceae
Ilex cornuta Lindl. & Paxton*	Burford Holly	Aquifoliaceae
Hedera helix L.	English ivy	Araliaceae
Bidens bipinnata L.	Spanish needles	Asteraceae
Carduus nutans L.*	nodding plumeless thistle	Asteraceae
Cirsium vulgare (Savi) Ten.*	bull thistle	Asteraceae
Helenium amarum (Raf.) H. Rock	bitterweed	Asteraceae
Hypochaeris radicata L.	hairy catsear	Asteraceae
Lactuca serriola L.	prickly lettuce	Asteraceae
Xanthium strumarium L.	rough cockleburr	Asteraceae
Nandina domestica Thunb.	sacred bamboo	Berberidaceae
Macfadyena unguis-cati (L.) A.H. Gentry*	catclawvine	Bignoniaceae
Lonicera japonica Thunb.	Japanese honeysuckle	Caprifoliaceae
Dioscorea bulbifera L.*	air yam	Dioscoreaceae
Elaeagnus pungens Thunb.	thorny olive	Elaeagnaceae
Elaeagnus umbellata Thunb.	autumn olive	Elaeagnaceae
Phyllanthus urinaria L.	chamber bitter	Euphorbiaceae
Triadica sebifera (L.) Small	tallowtree	Euphorbiaceae
Vernicia fordii (Hemsl.) Airy-Shawi	tungoil tree	Euphorbiaceae
Albizia julibrissin Durazz.	silktree	Fabaceae
Kummerowia striata (Thunb.) Schindl.	Japanese clover	Fabaceae
Lespedeza bicolor Turcz.	shrubby lespedeza	Fabaceae
Lespedeza cuneata (Dum.-Cours.) G. Don	Chinese lespedeza	Fabaceae
Pueraria montana (Lour.) Merr. var. *lobata* (Willd.) Maesen & S. Almeida	kudzu	Fabaceae
Senna obtusifolia (L.) Link	Java-bean	Fabaceae
Senna occidentalis (L.) Link	septicweed	Fabaceae
Sesbania herbacea (P. Mill.) McVaugh	bigpod sesbania	Fabaceae
Wisteria sinensis (Sims) DC.	Chinese wisteria	Fabaceae
Quercus acutissima Carruthers	sawtooth oak	Fagaceae
Egeria densa Planch.*	Brazilian waterweed	Hydrocharitaceae
Hydrilla verticillata (L. f.) Royle*	waterthyme	Hydrocharitaceae
Cinnamomum camphora (L.) J. Presl*	camphortree	Lauraceae
Lygodium japonicum (Thunb. ex Murr.) Sw.	Japanese climbing fern	Lygodiaceae
Melia azedarach L.	Chinaberry	Meliaceae

Fatoua villosa (Thunb.) Nakai	hairy crabweed	Moraceae
Ardisia crenata Sims*	hen's eyes	Myrsinaceae
Ligustrum lucidum Ait. f.	glossy privet	Oleaceae
Ligustrum sinense Lour.	Chinese privet	Oleaceae
Ligustrum vulgare L.	European privet	Oleaceae
Oxalis stricta L.	common yellow oxalis	Oxalidaceae
Polygonum cuspidatum Sieb. & Zucc.*	Japanese knotweed	Polygonaceae
Eichhornia crassipes (Mart.) Solms	common water hyacinth	Pontederiaceae
Rosa multiflora Thunb. ex Murr.	multiflora rose	Rosaceae
Salvinia molesta Mitchell*	kariba-weed	Salviniaceae
Ailanthus altissima (P. Mill.) Swingle*	tree of heaven	Simaroubaceae
Solanum viarum Dunal*	tropical soda apple	Solanaceae
Sphenoclea zeylanica Gaertn.	chickenspike	Sphenocleaceae
Verbena brasiliensis Vell.	Brazilian vervain	Verbenaceae

* In the vicinity but not yet documented from Fort Polk

National Park Service Exotic Plant Management Teams

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After habitat loss, invasive or exotic species are considered the greatest threat to global biological diversity; they are implicated in the listing of 42% of all species protected by the Endangered Species Act. Additionally, approximately 1.5 million acres of National Park Service (NPS) lands are infested by invasive plant species. Therefore, the threat of invasive species has grave implications for the preservation of natural and cultural resources throughout the NPS system. To effectively combat exotic plant species the National Park Service's established the Exotic Plant Management Teams (EPMT) in 2000. The EPMTs are modeled after the coordinated rapid response approach used in wildland fire fighting. The first test of the EPMT concept was conducted in 1997 at Lake Mead National Recreation Area (Nevada and Arizona). The success of Lake Mead's EPMT led to the establishment of EPMTs through funding from the Natural Resource Challenge. There are 16 EPMTS's serving over 209 parks controlling harmful invasive species that threaten natural and cultural resources. EPMT's have identified and treated over 17,000 acres and eradicated six species from parklands. EPMTs are also building capacity to meet the growing demand for information and technical resources to manage exotic plants

Key words: Biodiversity, EMPT, invasive species, Lake Mead

Invasive Grasses: Is it all a Numbers Game?

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Abstract

Grasslands, or the herbaceous layer of grassy woodlands or grassy forests, are commonly invaded by weedy grasses that become dominant in grazed situations, on roadsides and in areas that have been set aside for conservation such as National Parks. These invasive grasses have usually come from another country and tend to form monocultures and markedly reduce the plant biodiversity of the communities that they invade. They have been termed 'reproductively efficient grassy weeds' and appear to have a suite of characteristics which make them ideally suited for their invasive life style. Invasive grasses can be annual or perennial, cool-season or warm-season species and examples are *Vulpia* spp.L., (cool-season annual), *Nassella neesiana* (Trin. & Rupr.) Barkworth (cool-season perennial) and *Sporobolus fertilis* (Steud.) Clayton (warm-season perennial). The seed banks of these species can range from about 200 to 35,000 seeds/m^2 whereas those of native or sown perennial grasses in north eastern NSW may be one, two or even three orders of magnitude lower. Therefore, if a gap is created in grassland vegetation when an invasive grass is present, the species most likely to colonise the gap is the one with the largest seed bank. Gaps may be created by herbicides (either spot spraying or broad scale spraying), droughts, inappropriate grazing, fire or other means. I believe that the invasion by these grasses is simply a numbers game and the options of the landscape manager are often limited particularly when the use of tactical grazing by domestic livestock is not possible.

Key words: Grasses, invasive, seed banks

Introduction

Grasslands, or the herbaceous layer of grassy woodlands or grassy forests, are commonly invaded by weedy grasses that become dominant in grazed situations, on roadsides and in areas that have been set aside for conservation such as National Parks (Gardener and Sindel 1998; Downey and Leys 2004). These invasive grasses have usually come from another country and tend to form monocultures and markedly reduce the plant biodiversity of the communities that they invade (Grice et al. 2004; McArdle et al. 2004: Grice 2006). A common spin off in conservation areas is the destruction of habitat for animals that are native to the area to such an extent that their populations can become endangered, particularly if there are specific food or shelter plants that are essential for their well being (Grice et al. 2004; Vidler 2004).

These invasive grasses are often of low palatability to domestic livestock and are often relatively slow growing even in high fertility soils (Rossiter 1966; Gardener et al. 2005). Their low palatability would give them a competitive advantage under continuous grazing in that the competing, more palatable grasses would be selectively grazed to the advantage of the invasive grasses (Gardener et al. 2005). However, this competitive advantage would not

explain their invasive capacity in situations where domestic livestock are not present and the grazing pressure from native animals is low.

Gardener et al. (1996) have termed these species 'reproductively efficient grassy weeds' and they appear to have a suite of characteristics that make them ideally suited for their invasive life style. These characteristics may include their ability to produce large numbers of viable seeds, a long lasting soil seed bank and flexibility in their reproductive processes (Gardener et al. 1996).

Invasive grasses can be annual or perennial, cool-season or warm-season species depending on their origins. In general, these grasses are not invasive in their native land but have become problems in other countries where they have been either deliberately or accidentally introduced. So seriously are some of them regarded in New South Wales, Australia, that invasion by introduced perennial grasses has recently been declared a Key Threatening Process under the NSW Threatened Species Conservation Act.

I will use a cool-season annual, a cool-season perennial and a warm-season perennial to illustrate some characteristics of these grasses. The data presented come from north eastern New South Wales, but the implications are equally important for the eastern United States. The long-term average annual rainfall in this part of Australia varies from about 700 mm to about 1,200 mm with roughly equal winter and summer soil water availability (Lodge and Whalley 1989). However, the rainfall reliability is low and soil water can limit plant growth at any time of the year. Although the winters are cool, growth of cool-season species can continue throughout the winter over most of the region provided soil water is available (Lodge and Whalley 1989). The data for *Sporobolus fertilis* were collected on the coast at Valla, NSW at about the same latitude but lower elevation with warmer winters and a rainfall of about 1,700 mm with a marked summer dominance (Andrews et al. 1996).

Cool-season annual, *Vulpia spp.*

Vulpia bromides (L.) Gray and *V. myuros* (L.) C.C.Gmel mostly occur as mixed stands in grasslands in north eastern NSW (McIntyre and Whalley 1990) and originated in the Mediterranean region (Dillon and Forcella 1984; Groves 1986). *Vulpia bromoides* is generally the more abundant of the two in this region generally comprising about 61% of the *Vulpia* population and V. myuros about 38% with other species of *Vulpia* about 1% (McIntyre and Whalley 1990). It is generally impossible to separate the species at the seedling stage and so the data from studies described below simply refer to *Vulpia* spp.

Seeds of *Vulpia* spp. are shed in November/December and then germinate following rainfall events in the following year from February through to September (Dillon and Forcella 1984; Jones et al. 1992). The effects of standing herbage mass on the germination of seeds of both *V. myuros* and *V. bromoides* were investigated in 1991 in a podsolic soil near Armidale (Jones 1992). The herbage mass was manipulated using a range of herbicides and mowing treatments inside 25 x 25 m exclosures to give five levels from 13 to 4,133 kg/ha (Fig. 1). In February, knife cuts 5 mm deep and 1 m long were made in the different treatments and 200 seeds were individually sown into each cut. Seeds of each species of *Vulpia* were sown into separate cuts and there were 3 replications at each level of herbage mass.

Seedling emergence was recorded each month over the next 7 months (final record in September) and there was a negative relationship between herbage mass and the final cumulative number of seedlings for *V. myuros* (Fig. 1a). In contrast, the highest initial

emergence for *V. bromoides* was in the treatment with the lowest herbage mass but by September, there was no difference in cumulative emergence between treatments with the highest and the lowest herbage mass (Fig. 1b).

Seed harvested in December and sown in potting mix in a glasshouse in February gave close to 100% germination with *V. myuros* germinating somewhat faster than *V. bromoides* (Fig. 2). These results contrast with the staggered germination of seeds sown in the field (Fig. 1) and with the results from Dillon and Forcella (1984). From a separate field experiment, V. *bromoides* plants which emerged in March produced 53 times more seed than plants which emerged in July (Jones 1992). Even plants emerging as late as September produced at least one or two seeds therefore maintaining the seed bank.

Plant populations measured in 1990 at Armidale ranged from 386 to 35,952 plants/m^2 with a mean of 7,655 plants/m^2. Seed banks of *Vulpia* spp. were generally of the order of 200 to 35,000 seeds/m^2. Field studies near Armidale (Jones et al. 1992) showed that these seed banks could persist for about three years with about 1% of the seed bank surviving to the next year. This means that without the input of any further seeds, a seed bank of 35,000 seeds/m^2 would result in 350 seeds/m^2 surviving until the next year and 3.5 seeds/m^2 in the 3rd year. Such is the potential fecundity of these species, that under good conditions, the population could easily recover to its former level within two years (Jones et al. 1992).

Cool-season perennial, *Nassella neesiana*

Nassella neesiana (Trin. & Rupr.) Barkworth is a cool-season perennial grass native to temperate South America that has become an important weed in Australia in recent years (Gardener et al. 2003a). It can become dominant in grazed pastures and also invades roadsides and parklands and has been declared a Weed of National Significance (WONS) in Australia (Thorp and Lynch 2000: Gardener et al 2003a).

The main flowering period in Australia extends from November to February, depending on the rainfall pattern in the spring and early summer. A spring with high rainfall will lead to early flowering with a large number of flowering tillers and high seed production (e.g. 1996) whereas a dry spring and early summer will lead to sporadic and extended tiller production with a lower total number of seeds (Fig. 3, Gardener et al. 2003a). In addition to this flexible response to rainfall patterns, *N. neesiana* also produces cleistogenes (hidden seeds) inside the leaf sheaths on the lower nodes of the tillers. Cleistogene production is usually about 20 to 25% of the total seed crop and is not affected by clipping the tillers at three different levels (Gardener et al. 2003a).

Seed production can be as high as 28,000 seeds/m^2 of which about 41% can be incorporated into the seed bank (Gardener at al. 2003b). The lemmas have a hygroscopic awn attached which bury the seed in the surface soil and then break off. In dry years, as in 1995 and 1997, input into the seed bank is just sufficient to maintain it (Fig. 3). Seed banks can be of the order of 12,000 seeds/m^2 and the seeds have complicated dormancy responses. Seeds that had been buried in the soil for 2 years gave 90% germination in the laboratory whereas those that had been stored in the laboratory for the same period only gave 48% (Gardener et al. 2003b). Seedlings emerged from bare soil or from sown seed into bare soil following suitable rainfall events throughout the year but few seedlings were recorded from vegetated ground (Gardener 2003b). Survival of seedlings for up to 20 months was high and of the order of 30% to 78%. Assuming an initial seed bank of 7,000 seeds /m^2 and an exponential decline with no further seed input, the seed bank will still have about 10

seeds/m^2 after 12 years (Fig. 4). It appears that there is virtually no seed bank on the Pampas Plains of Argentina where this species occurs naturally and where it is not invasive (Gardener and Sindel 1998).

Warm-season perennial, *Sporobolus fertilis*

Sporobolus fertilis (Steud.) Clayton is one of a group of *Sporobolus* species that are invasive warm-season perennial grasses throughout the sub-tropics. It invades pastures, roadsides and conservation areas on the east coast of Australia from southern NSW to well into Queensland (Andrews et al. 1996). It is unpalatable to domestic livestock, particularly during the late summer and autumn when it becomes rank and produces vast quantities of seed. The seeds are small (about 1 mm long, Mallett 2005) and mature seeds have a loose pericarp which becomes sticky when wet, allowing the seeds to stick to animals and vehicles, falling off when they dry out (Andrews 1995).

Each spikelet can produce one floret and one seed, and the seeds, paleas, lemmas and glumes all fall at seed maturity. Therefore, potential seed production was estimated by counting the number of pedicels on sections of the inflorescences, calculating the total number of pedicels per inflorescence, and counting the number of inflorescences per unit area (Andrews et al. 1996). Actual seed production was estimated by placing seed traps at ground level below the plants in which the potential seed production was being estimated. Potential seed production commenced in December and continued until June whereas actual seed production commenced in January and continued on until July (Fig. 5). Total potential seed production for the year was about 668,000 seeds/m^2 and the actual about 146,000 seeds/m^2.

Seed banks were very variable and ranged from about 2,000 seeds/m2 to about 22,000 seeds/m2 with a mean of about 9,500 seeds/m^2. Only about 1.6% of the actual seed fall and 0.3% of the potential seed production was incorporated into the seed bank (Whalley et al. 1997), markedly less than that for *N. neesiana*. Higher seed predation of the much smaller *S. fertilis* seeds probably accounts for this difference between the species. Using an exponential seed bank decay over time, the time needed for the seed bank to fall to 15 seeds/m^2 varied between 3.3 to 9 years (Andrews et al. 1996).

Seedling emergence from vegetated plots was very low whereas emergence from bare plots followed rainfall events in the spring and early autumn (Fig. 6). Very little emergence occurred from late December until early March, even when suitable rainfall events occurred. Not only was seedling emergence from vegetated plots lower that that for bare plots, but few seedlings survived in the vegetated plots (Andrews et al. 1996). The lack of seedling emergence in the summer could result from the complicated responses of seed germination of this species to light and alternating temperatures (Andrews et al. 1997).

Seed banks in grazed pastures

Earl (1998) collected cores from grazed pastures at two locations in north eastern NSW in August at the end of winter in 1994 and examined the germinable seed bank by spreading the cores over washed sand in trays in an unheated glasshouse with natural lighting. The cores were watered to keep them moist for 4 weeks commencing 5th September, 19th December, 3rd April and 23rd June 1994 to detect species that might naturally germinate in the spring, summer, autumn and winter. The trays were allowed to dry out between watering periods. The site at "Strathroy" (Table 1) was dryer, on a soil of lower

fertility and at a lower elevation than the site at "Green Hills" (Table 2). The "Green Hills site had been sown to introduced grasses and clovers prior to 1965 but native grasses were dominant at the time of sampling. The "Strathroy" site had been cell grazed (Earl and Jones 1996) for 6 months and a grazing cell was in the process of being established at "Green Hills" when the samples were collected.

The preferred native perennial grasses from the grazier's perspective on these sites include *Austrodanthonia* spp., *Bothriochloa macra, Digitaria brownii, Elymus scaber*, native *Eragrostis* spp., *Eulalia aurea*, and *Microlaena stipoides*. With the exception of *Eragrostis leptostachya*, all of the above species had less than 1,000 seeds/m^2 (Tables 1 and 2). Lodge (2001) in a similar study, followed the germinable and total soil seed banks in native and sown pastures for three years in north eastern NSW. These pastures were exposed to either continuous grazing or rested in the spring and autumn. The seed banks of the individual grasses fluctuated from year to year depending on the timing of individual rainfall events and the management of the pastures. Again, with the exception of *Bothriochloa macra* (which some would see as an invading species e.g. Cook et al. 1976) the more highly regarded perennial grasses, both introduced and native had relatively small seed banks (Lodge 2001).

Discussion

There are three features common to the reproductive ecology of the above three invasive grasses. The first is the ability to produce a very large seed bank under favourable conditions. In the case of the two perennial species, the seed banks appeared to be very long-lived with up to 10 seeds/m^2 surviving after about 10 years with no further seed input.

The second is flexibility in flowering and seed production which is achieved by different mechanisms in each of the three species. The cool-season annual (*Vulpia* spp.) will germinate whenever suitable rainfall events occur during the seven months from late January to September. Although individual plants from the earlier cohorts will produce many more seeds than those from later, even plants germinating in September will produce a few mature seeds at the same time (October/November) as plants from earlier cohorts. The flowering period of the cool-season perennial (*N. neesiana*) is much more flexible and is either confined to the spring/early summer when soil water is plentiful or spread over several months following individual rainfall events in dryer years. In addition, it will produce cleistogenes at the lower nodes of the tillers even under close grazing or mowing. The warm-season perennial (*S. fertilis*) will likewise flower over many months and has the capacity to produce huge numbers of tiny seeds.

The third is that the emergence and survival of seedlings was far greater from bare soil than under herbaceous vegetation. This difference was not so marked for *V. bromoides* as it was for the other species.

The striking feature about the data presented in this paper is that the seed banks of the reproductively efficient grassy weeds are mostly one, two or three orders of magnitude greater that those of the preferred perennial grasses. Vulnerable species in grassland reserves, whether grasses or non-grasses, almost certainly have small seed banks. Yu (1999) recorded only 80 and 35 seeds/m2 for the vulnerable perennial grasses *Bothriochloa biloba* and *Dichanthium setosum* respectively under stands dominated by these species.

Lodge (2001) states that "However, seedbank dynamics are such that only a relatively few seeds of a particular species may be required for successful regeneration, provided that

conditions are favourable for that species and meet its requirements for germination, growth and seed set". My interpretation of the data presented in this paper is that once a gap in ground cover is created, then the species with the greatest number of seeds within that gap is likely to be the most successful at colonisation. This species is likely to be a reproductively efficient grassy weed if one is present in the community. Gaps may be created by herbicides (either spot spraying or broad scale spraying), droughts, inappropriate grazing, fire or other means. Once plants of a reproductively efficient grassy weed have become established, then the progression to dominance is often inevitable, particularly in climates with highly variable rainfall. This progression can be slowed or even reversed by management that limits the production of gaps and reduces inputs into the seed bank of the invasive species (e.g. by grazing management (Jones and Whalley 1993) or by the use of wick wipers instead of spraying for tall invasive grasses).

I believe that the invasion by these grasses is simply a numbers game and the options of the landscape manager are often limited particularly when the use of tactical grazing by domestic livestock is not possible.

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Table 1. Germinable seed banks of annual and perennial grasses from soil cores collected in late winter at "Strathroy" in north eastern NSW (from Earl 1998). Introduced species are indicated by *

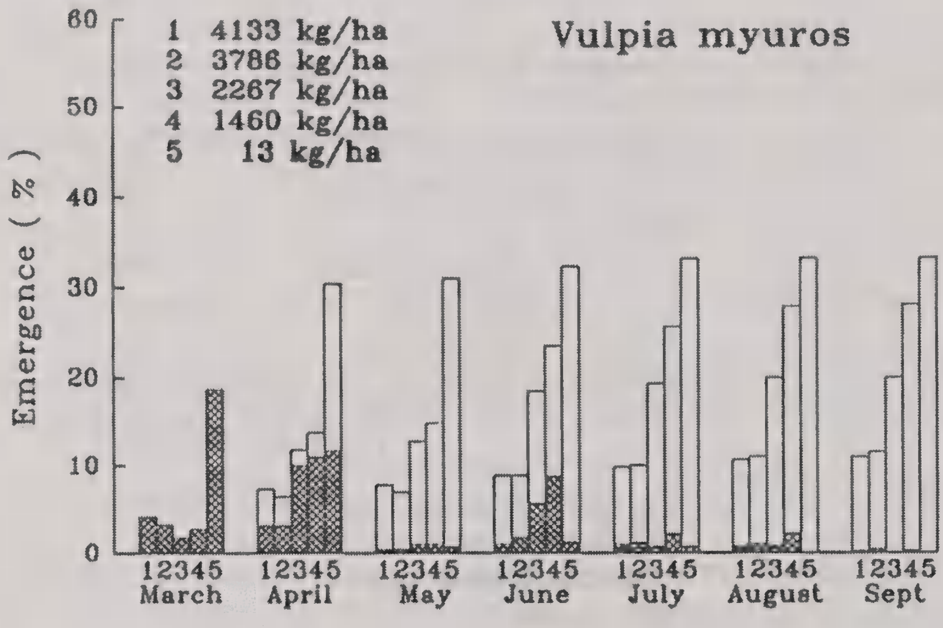
Annuals	Seedlings/m^2	Perennials	Seedlings/m^2
*Bromus racemosus**L.	366	*Sporobolus creber* De Nardi	5796
*Aira cupaniana**Guss.	247	*Eragrostis leptostachya* Steud.	4072
*Vulpia myuros**(L.) Gmel.	225	Other *Eragrostis* spp. Wolf	1852
*Briza minor**L.	153	*Eleusine tristachya**(Lam.) Lam.	1665
*Lolium rigidum**Gaudin	151	*Austrostipa scabra* (Lindl.) S.W.L.Jacobs & J.Everett	445
*Setaria pumila**(Poir.) Roem. & Schult.	7	*Digitaria brownii* (Roem. & Schult.) Hughes	368
*Hordeum leporinum**Link	3	*Panicum effusum* R.Br.	354
		Aristida ramosa R.Br.	338
		Chloris truncata R.Br.	287
		Microlaena stipoides (Labill.) R.Br.	169
		Eulalia aurea (Bory) Kunth	111
		Austrodanthonia spp. H.P.Linder	90
		Bothriochloa macra (Steud.) S.T.Blake	77
		Tragus australianus S.T.Blake	13
		*Paspalum dilatatum**Poir.	1

Table 2. Germinable seed banks of annual and perennial grasses from soil cores collected in late winter at “Green Hills” in north eastern NSW (from Earl 1998). Introduced species are indicated by *.

Annuals	Seedlings/m^2	Perennials	Seedlings/m^2
*Digitaria sanguinalis**(L.) Scop.	3258	*Poa pratensis**L.	2138
*Vulpia bromoides**(L.) Gray	2921	*Eleusine tristachya**(Lam.) Lam.	1224
Bromus spp.*L.	461	*Eragrostis* sp. “A”	976
*Eragrostis pilosa**(L.) P. Beauv.	364	*Sporobolus creber* De Nardi	820
Eragrostis trachycarpa (Benth.) Domin.	357	*Panicum effusum* R.Br.	445
*Digitaria ternata**(A. Rich) Stapf	268	*Bothriochloa macra* (Steud.) S.T.Blake	414
*Panicum gilvum**Launert	133	*Chloris truncata* R.Br.	349
*Poa annua**L.	10	*Poa sieberiana* Spreng.	128
		Sorghum leiocladum (Hack.) C.E.Hubbard	125
		Austrodanthonia spp. H.P.Linder	76
		*Phalaris aquatica**L.	23
		Elymus scaber (R.Br.) A.Löve	18

Fig. 1. Monthly (hatched) and cumulative (plain) emergence of (a) *V. myuros* and (b) *V. bromoides* from artificially established seed banks under a range of levels of pasture cover (from Jones 1992).

(a)



(b)

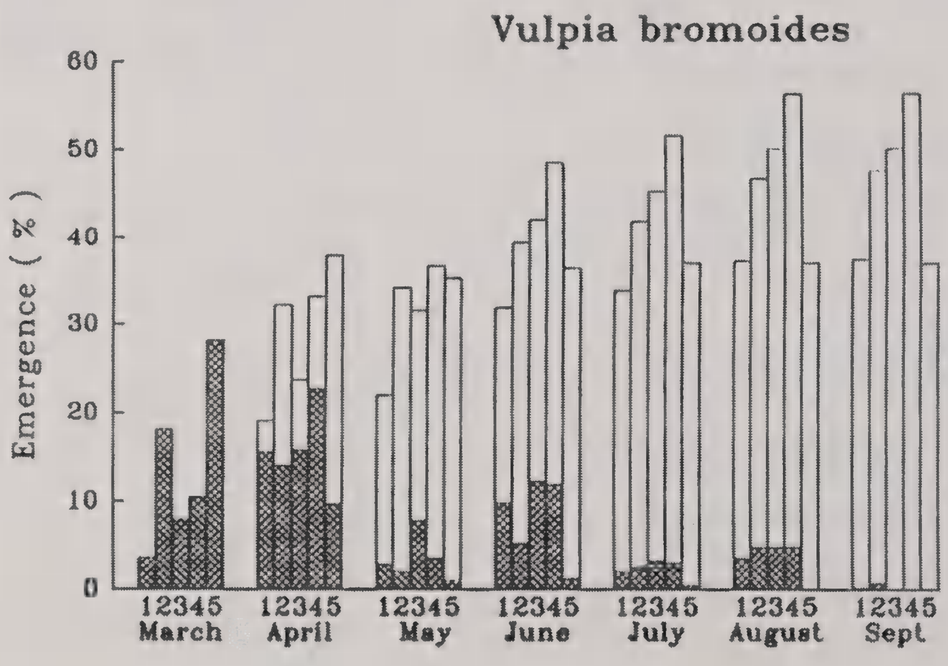


Fig. 2. Emergence of *Vulpia myuros* and *V. bromoides* in a glasshouse viability test of the seed sample used in the field trial (from Jones 1992).

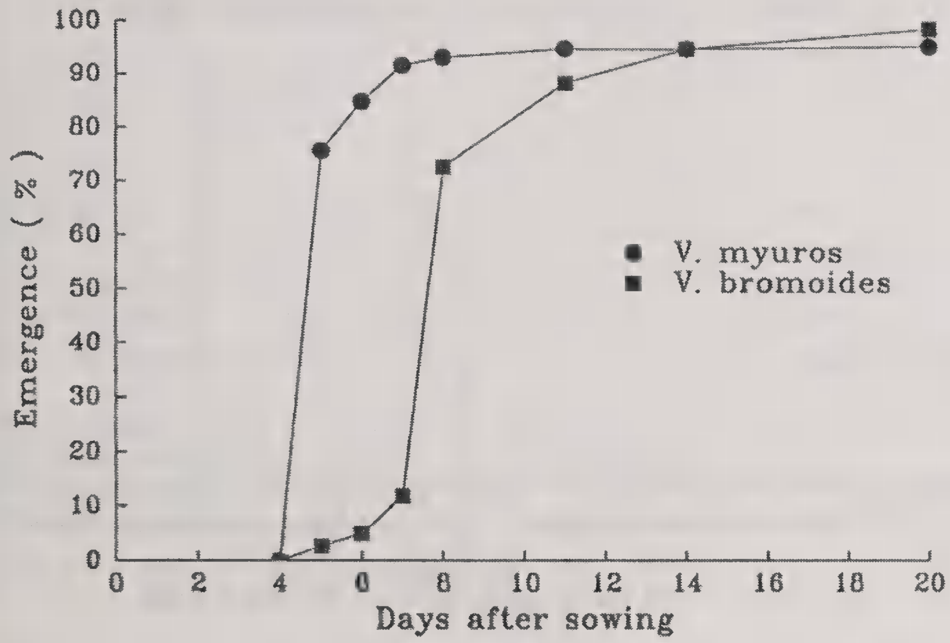


Fig. 3. Seed production and seed bank changes of *Nassella neesiana* over 3 years (from Gardener et al. 2003b).

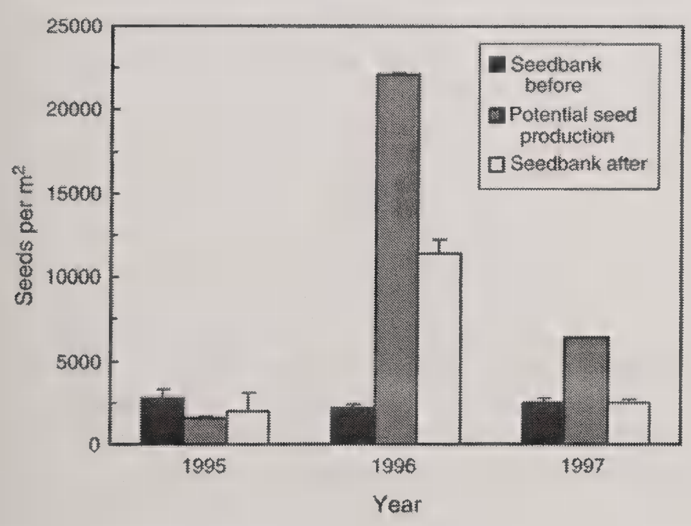


Fig. 4. An exponential decay curve fitted to changes in seed bank density without further seed input over 3 years (from Gardener et al. 2003b)

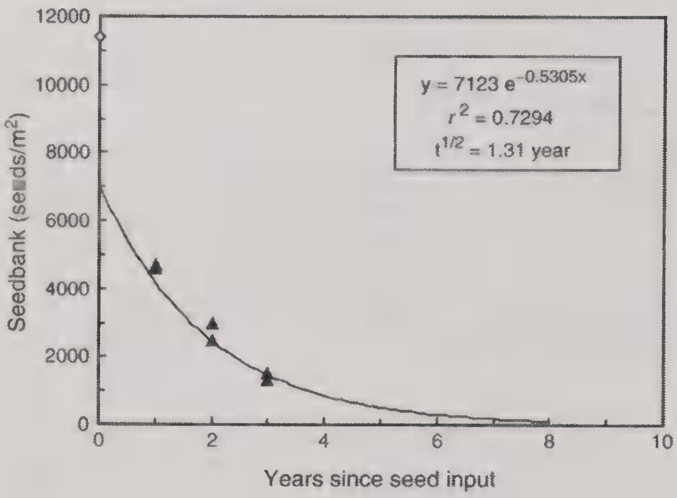


Fig. 5. Potential seed production (solid line and actual seed fall (dotted line) of *Sporobolus fertilis* (seeds/m^2) at Valla, NSW. Bars represent 1 standard error of the mean (from Andrews et al. 1996).

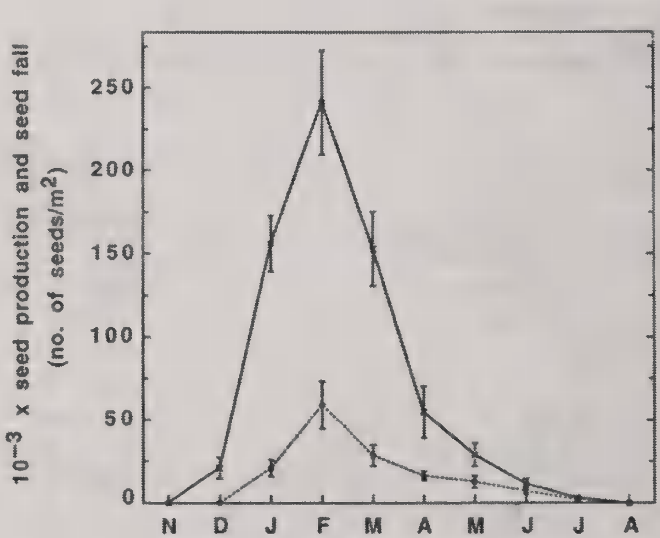
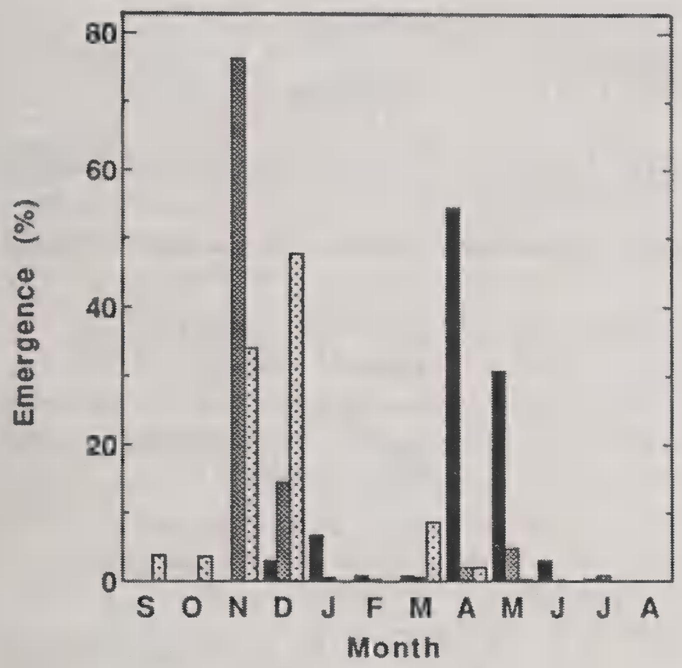


Fig. 6. Relative emergence (monthly emergence expressed as a proportion of seedling emergence from September to August of that year) in 1991-92 (solid bars) and 1992-93 (dotted bars) and 1993-94 (stippled bars), of *Sporobolus fertilis* at Valla, NSW (from Andrews et al. 1996).



Landscape Design

Got Grass?

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The use of ornamental/native grasses in the United States has increased dramatically in the last 10 years. Using native species and grasses as design elements within the landscape have created a new visual form of design. Grasses create movement, sound and winter interest making them very desirable additions to both commercial and residential landscapes. While the additions of these grasses have created landscapes with more intense beauty they have also created some assets and problems. To start with, the assets are very recognizable, it's the main reason most grasses are purchased and planted. They are color, form, movement, and sound, but the most important should be that the ecological needs are less than those of other plants. Once established they consume very little energy, both water requirements and maintenance is reduced to less than the usual landscape shrub and tree plantings. This makes them extremely sought after in commercial designs. The problems are not so recognizable and they can happen quickly creating a problem that maybe unfixable. Knowing that the main problem is the lack of knowledge by the homeowner/designer on things such as knowing native grasses from introduction, this can and will continue to changing along with the native plant movement. Understanding temperate zones and how they can make a grass invasive, that which is native in one place may become invasive in another. Lastly one of the biggest problems many designers of native landscapes confront is the public perceptions of grass, but there are ways to deal with public perceptions

Key words: Design elements, ecological needs, public perceptions, temperate zones

Got Shade? Native Grasses, Sedges and Rushes for Landscaping

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Abstract

Native grasses, sedges and rushes are invaluable assets for landscaping shaded areas. Efforts are needed to identify appropriate species and to incorporate them into landscape designs. The lack of knowledge of native plants, the failure of appreciating their uses, and the limited sources for purchasing them have combined to contribute to the absence of these native species in the cultural landscape.

Key words: Home gardeners, natural landscapes

Many home landscapes have partially, if not predominantly, shaded areas. In the past, gardeners have used Hostas and other non-native plants to fill these areas; or, they have actually removed all of the existing vegetation to create an environment more conducive to sun-loving bedding plants and garden center variety perennials. Native grasses, sedges and rushes offer an entirely different approach to utilizing these natural areas. By creating an environment that replicates natural habitats and by selecting a variety of native species that are well adapted to shaded areas, the home gardener can create a landscape that will afford a variety of blooms and foliage that will highlight the garden from early spring through winter. By following some simple procedures, these gardens can be maintained without irrigation, fertilizer and pesticides.

A wave of change is flowing through our gardens and landscapes. Garden designers and landscape architectures are increasingly becoming aware of the value and importance of native grasses, sedges and rushes. One factor that has deterred gardeners and landscapers from using native plants is the fear that they are invasive and therefore unmanageable. Many of our native grasses, sedges and rushes are truly garden-worthy. It is important to understand that being ornamental; however, is not the sole quality of these plants. They have a fundamental beauty *and* purpose in the cultural landscape.

There are a variety of ways native plants can be used in the garden and landscape. Gardening with native grasses, sedges and rushes allow us to explore and better understand the depth of creating a natural landscape. Grasses are the blanket of much of the natural world. They can reflect its every mood. Although they may be perceived to lack the brightly colored flowers of the broad-leaved flora, the subtleties of their shape, form and texture create a lasting beauty that span the seasons. A natural lawn can pulse with life in a way that heightens the senses and yet also soothes the soul. It also offers an ecologically sound habitat for wildlife that further enriches the gardening experience.

Native grasses also have an ease of cultivation. Often, they require little more than good soil. There are species that will thrive in full sun, dry shade, moist shade, and wet meadows and bogs. Like any garden plant, they require only timely weeding and annual grooming. These naturalized lawns can be managed using the simplest means. In many instances, they will never require mowing. Potential garden spaces on your property should

never be forced into submission as manicured lawns.

In the early 1950s, ornamental and native grasses were virtually unused in American gardens. As interest gradually increased in ornamental grasses, efforts were made to find new species from remote corners of the globe. Attention was also given to raise and introduce new varieties, especially those exhibiting variegated foliage. While the search worldwide for new and unusual species of ornamental grasses is well-underway, the recognition of the beauty and usefulness of our native grasses, sedges and rushes in the cultural landscape has lagged woefully behind.

Mounding forms of grasses are of the most importance to us, because they tend to be non-aggressive. There is a simple classification of the mound form of grasses. First is root type: either running or clumping. Clumping grasses form tight, dense mounds that increase steadily but do not spread aggressively. Running grasses, however, spread by means of vigorous rhizomes or stolons and can quickly overtake a garden area. Leaf mound shapes include tufted, mounded, upright, upright-divergent, fountain-like, arching and trailing.

Sedges are close botanical cousins of the grasses. Sedges comprise approximately 115 genera and are confined to temperate, cool temperate and arctic regions. They often grow in damp or waterlogged areas, but also inhabit dry woodlands. Most sedge species are perennial, and many are evergreen. The stems of sedges are solid and triangular in section. Leaf sheaths are closed, completely surrounding the stem. Leaves are usually V-shaped, with a prominent keel. Their flower heads are quite distinct from grasses. The spikelets are arranged in heads or spikes. They are never paniculate. Roots of sedges are rhizomatous and never fibrous and can withstand competition from tree roots. With the proper choice of species, a gardener can recreate the character of the native sods that existed before the introduction of the modern, suburban, manicured lawn.

The Rush family (*Juncaeae*) is a small one. There are approximately 400 species worldwide. Most of the rushes grow in damp cool areas. In their flower structure, they are more like lilies than grasses. The most important genus for our purposes is *Juncus*.

I have identified the following native species for dry shade areas.

1. *Carex albursina* (White Bear Sedge). A striking large-leaved sedge found in deep, rich woods. It would make an excellent substitute for diminutive hostas.
2. *Carex appalachia* (Appalachian Sedge). This is a fine-textured native sedge with light to medium green foliage. Its weeping foliage seems to curve and swirl as if in motion. It prefers open shade with average to dry soil and colonizes quickly. Average height is one foot.
3. *Carex cherokeensis* (Cherokee Sedge). Although not well known, this sedge is an extremely attractive species for woodland settings. It has light green foliage and grows to one foot in height.
4. *Carex flaccosperma* (Blue Wood Sedge). A strong clump-forming sedge with glaucous blue to blue-green and slightly quilted leaves. It spreads slowly and is quite drought and shade tolerant. Average height is 6 to 10 inches.
5. *Carex pennsylvanica* (Pennsylvania Sedge). This sedge can easily be identified because of its light, yellow green leaves. It makes a wonderful groundcover for average to dry deciduous shade and is a slow spreading clump former growing to about eight inches. Height is 1 foot.
6. *Carex plantaginea* (Seersucker Sedge). The shiny deep green leaves are puckered like a Christmas ribbon. It is an excellent evergreen groundcover for average to moist shade. Height is 1 foot.

7. *Carex platyphylla* (Silver Sedge). This is a clump-forming sedge with powder blue leaves up to an inch wide. It spreads slowly to form a textured groundcover in moist or average soil, but tolerates dry shade. Average height is 8 to 12 inches.
8. *Carex grayii* (Mace Sedge). This interesting sedge is known for its unique pale green spiked seed heads that resemble medieval maces. Although found in moist shaded areas, it performs well in drier conditions. Attains three feet in height.
9. *Carex sparganiodes* (Burreed Sedge). This is a woodland species that grows in moist to dry shade. It can be used for soil stabilization on shaded slopes. Grows from 1 to 2 feet in height.
10. *Chasmanthium latifolium* (Northern Sea Oats). Grows in clumps with wiry stems naked for much of their length. It is an excellent choice for dry shade areas. Grows from 1 to 2 feet.
11 .*Cymophyllus fraseri* (Fraser's Sedge). This is by far one of the most striking species of sedge. It has long glossy, evergreen strap-like leaves about 1 ½ inch wide and numerous flowers on nakes stems that are like little white pom-poms. It can be planted in cool, rich woodland gardens with good drainage. Height is about one foot.
12. *Danthonia spicata* (June Grass). This species is easy to identify because of the curly dried leaves at its base that are present year-round. It is a short-leaved, light green, tufted sedge found on dry and poor sandy or gravelly soils. This species has an excellent potential as a groundcover for dry shade areas and could be used effectively in a rock garden setting. It grows 4 inches to 2 feet.
13. *Diarrehena americana* (Beak Grass). Possesses graceful arching, glossy, bright green foliage that turns golden in fall. It prefers shaded areas and grows to 1 foot in height.
14. *Elymus hystrix* (Bottlebrush Grass). Although native to open woods and moist wooded floodplains, it is also a widely adaptable prairie grass. Its upright dark green blades contrast nicely with the more delicate bottlebrush infloresence. It prefers bright shade and reaches a height of 3 to 4 feet.
15. *Erianthus giganteus* (Sugarcane Plumegrass). Found along the edges of dry woods, this species can be used in place of Miscanthus sinensis.
16. *Juncus effusus* (Common Rush). This clump-forming rush has dark, evergreen foliage. It can prosper in wet or dry conditions, although it does best in low spots. The leaves are round and reach about 4 feet. Three cultivars of Juncus effusus have renewed interest in this species. 'Curly Wurly' offers tightly coiled, shiny round foliage creating a petite curly rush. 'Frenzy' is a variegated rush with distinct yellow strips running along the length of its corkscrew-like foliage. 'Unicorn' has similar curly leaves, but is more robust and has darker keaves,
17. *Juncus tenuis* (Path Rush). Often found on paths in woods, this small, bright green plant is useful as an excellent groundcover and can be planted in wetter soils.
18. *Juncus torreyi* (Torrey's Rush). The round seed heads on this species make it an attractive addition to moist and shaded site.
19. *Luzula acuminata* (Hairy Woodrush). This interesting, attractive plant with grass-like leaves is adorned with wispy, white hairs. It thrives in part shade and average soil and can be used effectively in sunny woodland plantings. It reaches 20 inches in height.
20. *Luzula multiflora* (Common Woodrush). The leaves of this woodrush are a beautiful red-brown. It prefers sun-to-part shade and average soil. Grows 6 inches to 2 feet.
21. *Poa sylvestris* (Sylvan Bluegrass). Found under shade of deciduous trees in rich well drained soil, its soft narrow leaves and delicate panicles of small white flowers emerge from

clumps. Reaches 1 foot in height.
22. *Sorghastrum nutans* (L.) Nash (Indiangrass). This is one of the most handsome of native grasses. It does well in full sun-to-part shade and average-to-rich soil. Its translucent yellow-to-deep gold fall color is a sight to behold.

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Restoration

Native Grasses of the Cajun Prairie in Southwest Louisiana

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Abstract

Cajun Prairie once covered 2.5 million acres in southwest Louisiana but has been reduced by agricultural practices (tilling) to less than 100 acres in small, disjunct remnant strips along railroad rights of way. Information from the remnants indicates the presence of a large vascular flora with more than 500 taxa. The graminoid flora consists of 134 taxa with 78 (72 native) grasses (Poaceae), 49 (47 native) sedges (*Cyperaceae*), and 7 (7 native) rushes. (*Juncaceae*).

Key words: Cajun Prairie, flora, graminoids

Background

Cajun Prairie once covered 2.5 million acres in southwest Louisiana but has been reduced by agricultural practices (tilling) to less than 100 acres. The remaining Cajun Prairie is in small, disjunct remnant strips along railroad rights of way. A limited number of restoration projects are ongoing to preserve this threatened ecosystem (Allen and Vidrine 1989, 2004; Allen and Grafe 2004). Since the late 1980's, this ecosystem has been examined and its vascular flora was presented at the 17th North American Prairie Conference (Allen et al 2001).

Methods

Since 1987, the authors have visited and recorded all vascular plant species presence in Cajun Prairie remnants and restorations throughout the range of this ecosystem in southwest Louisiana. The presence of most species has been documented with herbarium specimens that are on deposit in Louisiana herbaria. The senior author is the recognized grass expert for Louisiana (Allen et al 2004). Sedge and rush taxa were identified using keys and descriptions from the appropriate floras (Correll and Johnston 1970; Godfrey and Wooten 1979; Radford et al 1968).

Results

The Cajun Prairie flora consists of 512 taxa in 92 families and 277 genera (Allen et al 2001). The graminoid flora of this ecosystem includes 134 taxa with 78 (72 native) grasses (Poaceae), 49 (47 native) sedges (Cyperaceae), and 7 (7 native) rushes (Juncaceae) (Table 1). The most diverse genera include *Cyperus* and *Rhynchospora*, each with 12 taxa. Four genera have 7 taxa each including the grass genera *Dichanthelium* and *Paspalum*, the sedge

genus *Carex*, and the rush genus *Juncus*. The native or non-native status of these taxa is taken from the on-line Plants Database (USDA, NRCS 2006).

Discussion

The Louisiana graminoid flora consists of 693 taxa (Allen et al 2004; Thomas and Allen 1993; USDA NRCS 2006); the graminoid flora of Cajun Prairie is 134 taxa or 19.3%. The Louisiana grass flora is 408 taxa of which 78 (19.1%) occur in Cajun Prairie, the sedge flora is 256 taxa of which 49 (19.1%) occur in Cajun Prairie, and the rush flora is 29 of which 7 taxa (24.1%) occur in Cajun Prairie. Observational notes indicate the more common grasses are switchgrass (*Panicum virgatum* L.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), slender bluestem (*S. tenerum* Nees.), big bluestem (*Andropogon gerardii* Vitman), Indian grass (*Sorghastrum nutan* (L.) Nash), and eastern gama grass (*Tripsacum dactyloides* (L.) L.).

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Table 1. List of graminoid (grass, sedge, and rush) taxa from Cajun Prairie in southwest Louisiana.

Cyperaceae
Bulbostylis capillaris (L.) Kunth ex C.B. Clarke
Carex alata Torr.
Carex albolutescens Schwein.
Carex cherokeensis Schwein.
Carex complanata Torr. & Hook.
Carex frankii Kunthb
Carex microdonta Torr. & Hook.
Carex vulpinoidea Michx.
Cladium mariscus (L.) Pohl ssp. *jamaicense* (Crantz) Kükenth.
Cyperus acuminatus Torr. & Hook. ex Torr.
Cyperus croceus Vahl
Cyperus echinatus (L.) Wood
Cyperus erythrorhizos Muhl.
Cyperus haspan L.
**Cyperus iria* L.
Cyperus oxylepis Nees ex Steud.
Cyperus pseudovegetus Steud.
Cyperus retrorsus Chapman
**Cyperus rotundus* L.
Cyperus strigosus L.
Cyperus virens Michx.
Eleocharis microcarpa Torr.
Eleocharis montana (Kunth) Roemer & J.A. Schultes
Eleocharis obtusa (Willd.) J.A. Schultes
Eleocharis quadrangulata (Michx.) Roemer & J.A. Schultes
Eleocharis tuberculosa (Michx.) Roemer & J.A. Schultesb
Fimbristylis autumnalis (L.) Roemer & J.A. Schultes
Fimbristylis miliacea (L.) Vahl
Fimbristylis puberula (Michx.) Vahl
Fuirena pumila (Torr.) Spreng.
Isolepis carinata Hook. & Arn. ex Torr.
Kyllinga brevifolia Rottb.
Kyllinga odorata Vahl
Rhynchospora caduca Ell.
Rhynchospora cephalantha Gray
Rhynchospora chalarocephala Fern. & Gale
Rhynchospora colorata (L.) H. Pfeiffer
Rhynchospora corniculata (Lam.) Gray
Rhynchospora elliottii A. Dietr.
Rhynchospora globularis (Chapman) Small
Rhynchospora glomerata (L.) Vahl
Rhynchospora harveyi W. Boott

Rhynchospora microcarpa Baldw. ex Gray
Rhynchospora pusilla Chapman ex M.A. Curtis
Rhynchospora rariflora (Michx.) Ell.
Scleria ciliata Michx.
Scleria pauciflora Muhl. ex Willd.
Scleria reticularis Michx.
Scleria verticillata Muhl. ex Willd.

Juncaceae
Juncus brachycarpus Engelm.
Juncus effusus L.
Juncus marginatus Rostk.
Juncus nodatus Coville
Juncus polycephalus Michx.
Juncus tenuis Willd.
Juncus validus Coville

Poaceae
Agrostis hyemalis (Walt.) B.S.P.
Alopecurus carolinianus Walt.
Andropogon gerardii Vitman
Andropogon glomeratus (Walt.) B.S.P.
Andropogon gyrans Ashe var. *gyrans*
Andropogon ternarius Michx.
Andropogon virginicus L.
Anthaenantia rufa (Nutt.) J.A. Schultes
Aristida longispica Poir. var. *longispica*
Aristida oligantha Michx.
Aristida purpurascens Poir. var. *purpurascens*
Axonopus fissifolius (Raddi) Kuhlm.
Bothriochloa exaristata (Nash) Henr.
**Bothriochloa ischaemum* (L.) Keng
Bothriochloa longipaniculata (Gould) Allred & Gould
Briza minor L.
Bromus catharticus Vahl
**Chloris canterai* Arech.
Coelorachis cylindrica (Michx.) Nash
Coelorachis rugosa (Nutt.) Nash
Ctenium aromaticum (Walt.) Wood
Cynodon dactylon (L.) Pers.
Dichanthelium aciculare (Desv. ex Poir.) Gould & C.A. Clark
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark
Dichanthelium dichotomum (L.) Gould var. *dichotomum*
Dichanthelium oligosanthes (J.A. Schultes) Gould var. *scribnerianum* (Nash) Gould
Dichanthelium ovale (Ell.) Gould & C.A. Clark
Dichanthelium scoparium (Lam.) Gould

Dichanthelium sphaerocarpon (Ell.) Gould var. *sphaerocarpon*
Digitaria ciliaris (Retz.) Koel.
Digitaria cognata (J.A. Schultes) Pilger
Digitaria filiformis (L.) Koel.
Digitaria ischaemum (Schreb.) Schreb. ex Muhl.
Digitaria violascens Link
Echinochloa crus-galli (L.) Beauv.
Eragrostis bahiensis (Schrad. ex J.A. Schultes) J.A. Schultes
Eragrostis elliottii S. Wats.
Eragrostis hirsuta (Michx.) Nees
Eragrostis lugens Nees
Eragrostis refracta (Muhl.) Scribn.
Eragrostis spectabilis (Pursh) Steud.
Gymnopogon brevifolius Trin.
Leersia hexandra Sw.
Limnodea arkansana (Nutt.) L.H. Dewey
Lolium perenne L.
Muhlenbergia capillaris (Lam.) Trin.
Panicum anceps Michx.
Panicum brachyanthum Steud.
Panicum hemitomon J.A. Schultes
Panicum rigidulum Bosc ex Nees var. *rigidulum*
Panicum virgatum L.
**Paspalum dilatatum* Poir.
Paspalum floridanum Michx.
Paspalum laeve Michx.
Paspalum plicatulum Michx.
Paspalum praecox Walt.
Paspalum setaceum Michx.
**Paspalum urvillei* Steud.
Phalaris angusta Nees ex Trin.
Phalaris caroliniana Walt.
Schizachyrium scoparium (Michx.) Nash
Schizachyrium tenerum Nees
Setaria parviflora (Poir.) Kerguélen
Setaria pumila (Poir.) Roemer & J.A. Schultes
Sorghastrum nutans (L.) Nash
**Sorghum halepense* (L.) Pers.
Spartina spartinae (Trin.) Merr. ex A.S. Hitchc.
Sphenopholis obtusata (Michx.) Scribn.
Sporobolus compositus (Poir.) Merr.
**Sporobolus indicus* (L.) R. Br.
Sporobolus junceus (Beauv.) Kunth
Sporobolus silveanus Swallen
Steinchisma hians (Ell.) Nash
Tridens ambiguus (Ell.) J.A. Schultes

Tridens strictus (Nutt.) Nash
Tripsacum dactyloides (L.) L.
Urochloa platyphylla (Munro ex Wright) R. Webster
Vulpia octoflora (Walt.) Rydb.

* non-native taxon

Attempts to Enhance Node Activation in Rhizomes of River Cane (*Arundinaria gigantea*)

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Abstract

River cane [*Arundinaria gigantea* (Walt.) Muhl.], occupies only 2% of its original habitat. Attempts to reintroduce river cane to new locations, as ramets, are extremely difficult. Transplanting large culms of bamboo is extremely labor-intensive and seeding is limited by a prolonged juvenile growth stage. The only practical way to establish new colonies is through propagation and planting of large numbers of small plantlets. Our research used rhizome sections obtained from a single established genotype grown in a sunken 5-gallon pot. Rhizomes were collected in March, sectioned and sorted into visibly active nodes (AN) and viably dormant nodes (DN). These groups were soaked for 0, 5, 30, or 60 minutes in plant growth regulator (PGR) solutions for a total of 27 treatments. Rhizome sections were planted in flats and maintained in a greenhouse. Fastest response (2 weeks) was from terminal meristems. Fastest treatment response was (at 4 weeks) from the 60-minute warm water soak of AN. Benzylaminopurine (BAP) treatments positively affected shooting of DN, whereas gibberellin 4 (GA) treatments negatively affected shooting of AN and DN. No water-soak/no palnt growth regulator (PGR) treatment of DN resulted in the lowest final shooting response (30%). Use of properly maintained potted stock plants may be the key to large-scale production of river cane. A single 4-culm plant yielded 324 rhizome sections for this research.

Key words: *Arundinaria*, plant growth regulators, propagation, river cane

Introduction

Switch cane or river cane is the only native bamboo found in North America (Marsh, 1977). Historic accounts of extensive stands of river cane known as canebrakes abound. European settlers often chose the location of their homestead based on the presence of extensive canebrakes as an indicator of fertile soil. As the European population increased in the southeastern frontier, canebrake acreage declined substantially. Current estimates suggest that river cane only occupies 2% of its original land area (Noss, et al. 1995). Most authors indicate that canebrakes were located in all of the riparian ecosystems of the eastern U.S.(Delcourt, 1976; Meanley, 1972; Platt and Brantley, 1997). Large canebrakes occurred in the alluvial floodplains, at the first ridge, or on natural levees along rivers and creeks (Delcourt 1976). Hudson (1976) reports that canebrakes along the Mississippi River frequently occupied ridges roughly 24 feet above normal river flow and extended inland for miles. The natural location of these canebrakes would indicate that they had significant impact controlling erosion of riverbanks. The expansive rhizome/root system acts to tie one culm to another, stabilizing the entire colony, while the dense stand of culms would act to screen and seine flotsam from flood waters. Once waters receded, this organic material

would be deposited on the ground of the canebrake, making soils under these brakes especially fertile.

The extreme contraction of river cane ecosystems in the U.S. has caused concern among scientists (Noss et al. 1995; Platt et al. 2001). These researchers indicate that river cane systems are endangered. Conservation of existing stands should be a high priority and restoration efforts should be given significant attention.

Restoration efforts depend on the ability to propagate the organism. While propagation of leptomorphic (running) bamboos has been known since the great Chinese dynasties, applying those propagation techniques to native river cane stands is something quite different. Brantley and Platt (2001) indicate that workable river cane restoration techniques are currently lacking. Although restoration sites are available, techniques necessary to produce large numbers of propagules (sprouts, seedlings, or rhizomes) have not been developed (Platt and Brantley 1992; 1993; 2001). It is the lack of propagation and management techniques that hinders restoration efforts (Dattilo and Rhoades 2005). Restoration efforts by Dattilo and Roades (2005) and Cirtain et al. (2004) have focused on fertility management to maximize cane growth after transplant. Dattilo and Roades (2005) used crown division as a propagation method (Bell, 2000). These researchers lifted clumps roughly 20 inches in diameter with three to eight culms from an existing stand of river cane, transplanting these clumps to the test site. Curtain et al. (2004) utilized seedlings in their study. While both techniques showed success, dividing and transplanting bamboo crowns is extremely labor intensive and ramets frequently develop an embolism which causes existing culms to defoliate or die back completely. Seedling propagation is considerably easier, but the extended juvenility of bamboo makes seed availability an issue. Also, seedling development is exceedingly slow. It may take 2-3 years before a seedling will produce rhizomes. The objective of this study was to determine if plant growth regulators (PGR) commonly in use could enhance rhizome node activation to stimulate axillary shoot growth in rhizome segments of river cane.

Materials and Methods

Large quantities of rhizomes were obtained from a single river cane plant (genotype 'Oktoc'). The stock plant, consisting of four culms, had been maintained in a 5-gallon pot sunk in the ground for 2 years. During this 2-year period the stock plant was maintained in deep shade under fertility and irrigation to maintain deep green leaf color. On March 25, 2006, the stock plant was un-potted and 35 rhizomes were removed. Immediately after rhizome removal the stock plant was repotted back into a 5-gallon pot and watered heavily. Rhizome material was re-coiled and placed in plastic bags containing a 0.75% benomyl solution and refrigerated at 40°F for 9 days to maintain viability until they could be used. Rhizome material was removed from refrigeration and was cut into 2-inch sections each containing two to three nodal rings. The distal meristem was removed from all rhizomes and used as a separate treatment. Only sections proximal to the rhizome meristem were exposed to PGR treatments. After sectioning, rhizome pieces were divided into 2 groups based on the activity of the node; visibly active nodes (AN) or dormant nodes (DN). A minimum of 10 rhizomes sections were soaked for 0, 5, 30 or 60 minutes in: warm water (85°F), 1000 ppm benzylaminopurine (BAP), 1000 ppm, gibberellin 4 (GA), or 1000 ppm BAP+1000 ppm GA. After soaking, rhizome sections were rinsed in tap water, planted in flats of 50:50 sand:peat (v/v) and watered to saturation. Flats were watered daily. Shooting

observations were collected at 4, 5, 8, and 9 weeks after planting. The experiment was ended at 9 weeks. At the end of the experiment, rhizome sections were excavated and rhizome sections with shoots were assessed for root production. Rhizome sections without shoots were examined for meristem activity.

Results and Discussion

Response Time: Treatments showing relatively large amounts of shooting (visible shoot growth above soil level) at 4 weeks were the terminal rhizome meristems (11%) and the 60-minute water-soak of AN (30%). The rapid response from the terminal rhizome meristems was expected as these were actively growing and green at the time of rhizome harvest and planting. By Week 5, the 60-minute water soak of AN had achieved 70% shooting and terminal rhizome meristems were at 23% shooting. By Week 8 of the experiment the greatest positive response was observed among all treatments of the active nodes. The 60-minute water-soak of AN had reached 90% shooting and terminal rhizome meristems were at 46% shooting. No treatment of AN was at 70% shooting by this time. Other water-soak treatments responded favorably. Five- and 30-minute water-soaks of AN gave 40 and 50% shooting, respectively. BAP-soaks of AN for a duration of 5- 30- and 60-minutes gave 50, 40, 90% shooting by 8 weeks, respectively.

Overall, those nodes observed as AN responded quickly when planted. This is not unexpected since once removed from the apical dominance of the existing culms and terminal rhizome meristem one would expect the onset of active growth.

Active vs. Dormant Node Response: The response of AN to planting/treatment is not surprising. The test of success would be the ability to activate nodes that were observed to be dormant (DN) at the time of treatment. DN, in general responded much slower and in lower numbers than the AN. While there was shooting of some DN by the Week 5 it was limited to 10-20%. At Week 8 significant shooting was observed for two basic groups of DN: those that received a water-soak treatment or those that received a BAP-soak. Five- and 30-minute water-soaks of DN gave 50 and 40% shooting, respectively. The BAP-soaks of DN for 5- 30- and 60-minutes gave 50, 60, 70% shooting by Week 8 , respectively. The untreated control DN response was 20% for this time period. It appears that the warm water soak and the treatment with 1000 ppm BAP positively affected the shooting of DM.

Total Number of Propagules Produced: At the end of 9 weeks the experiment was ended and individual rhizome sections were assessed for propagule potential. Those rhizome pieces with shoots would be an obvious success, but until the end of the experiment, meristem activation (without shoot production) could not be ascertained. All rhizome sections were excavated, washed in clean water so the nodal regions could be examined. Shoot number, active (but no surface shoot) meristems and non-responsive/dead rhizome sections were recorded. Results for AN are generally very good, with all treatments yielding 50% or better actively living propagules. Nine of 13 treatments gave 70% or better living propagules. However, the ability to generate actively growing nodes, from actively growing nodes should not be difficult. It is important to look at deviation from the untreated control. The successful propagule percentage for AN control is 100%. Comparing all AN treatments, only BAP treatments of 30- and 60- minutes maintained the success of the control. When GA was included propagule production decreased. When we examined the results for the DN,

percentages above the control (30%) would indicate success. Treatments of BAP soaking or 60-minute water significantly increase the positive response.

Mother/Stock Plant: While the PGR treatments produced noticeable and significant results, it is as important to realize that the experiment would not have been performed as easily without the availability of the large amount of rhizome material that was necessary. The concept of maintaining stock plants specifically for propagation is a concept widely utilized in the horticulture industry, but not in conservation. Maintenance of stock plants under optimal growth conditions in socket pots or pot-in-pot technique is also widely used in horticulture. Containing river cane mother plants in pots causes elongating rhizomes to circle within the pot. Such growth makes annual harvest of these rhizomes highly efficient. Prior attempts by these researchers to harvest rhizome material from native stands were extremely laborious and limited experiment size. It should also be noted that rhizomes were harvested only once, in the spring. Research by Cirtain (dissertation pending) on macropropagation of river cane has shown the greatest positive response from rhizomes obtained during spring (January-March) and trails off dramatically after that.

Conclusions

A 1000 ppm soak in BAP stimulated shooting in DN. The GA treatment had a negative affect on AN and DN growth. While the PGR results are significant, as important is the concept of maintaining plant material under optimal growth conditions in containers to simplify rhizome harvest and ramet multiplication. While we are working with a native species, for maximum propagation efficiency we must make use of proven horticultural systems if we are to maximize output.

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Restoration of a Wet Pine Savanna at Moores Creek National Battlefield

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Abstract

This wetlands restoration project was designed to restore a degraded 4-acre wet meadow (savanna) to a landscape reflecting its possible appearance at the time of the 1776 battle of Moores Creek Bridge. Desired outcomes included: restore a natural drainage pattern to the savanna; establish and increase the abundance of characteristically dominant savanna bunchgrasses such as wire grass (*Aristida stricta* Michx.), savanna muhly [*Muhlenbergia expansa* (Poir.) Trin], Carolina dropseed [*Sporobolus pinetorum* A.Weakley & P.M. Peterson], and toothache grass [*Ctenium aromaticum* (Walt.) Wood] through prescribed burning and planting nursery grown plants (from wild-collected seed); increase and maintain species diversity and richness for non-dominant characteristic savanna species; and improve the habitat for state listed plant species and federal plant species of concern by discouraging the growth of invasive plants such as sweet gum and blackberry. Groundwater monitoring wells and staff gauges were used to establish a hydrologic baseline with changes in the savanna's drainage system designed to be reversible if needed. Volunteers hand harvested enough seeds to grow more than 25,000 plants and carried out most of the planting. The contracted grower provided invaluable information about successful seed harvest requirements and re-introduction of these bunchgrass species. This project was successfully carried out over the course of a decade by a small staff with limited natural resources backgrounds.

Key words: Bunchgrass, National Park Service, restoration, savanna

Introduction

Moores Creek National Battlefield is an 87-acre Revolutionary War battlefield located near Wilmington, NC. In 1995, the park initiated a wetlands restoration project to restore a degraded 4-acre wet meadow (savanna) to a landscape reflecting the likely appearance of the area at the time of the 1776 battle of Moores Creek Bridge.

Project Objective: Restore a degraded wetland in a culturally important landscape with the following desired outcomes:

- Restore a natural drainage pattern to the savanna.
- Establish and increase the abundance of characteristically dominant savanna bunch grasses through prescribed burning and planting nursery grown plants from seed collected in the wild.
- Increase and maintain species diversity and richness for non-dominant characteristic savanna species.
- Improve the habitat for state listed plant species and federal plant species of concern by discouraging the growth of invasive plants such as sweet gum and blackberry.

The savanna was ditched in first half of the 20th century to drain the surrounding area in order for vehicle traffic to reach the edge of the battlefield proper. A new trail system in the 1970s changed visitor vehicle access, ended the need for managed drainage in the savanna, but the ditch and all drains remained. From the 1930s through the 1980s a majority of the savanna was managed for turf grasses. The site contains relic populations of insectivorous plants including Venus flytrap (*Dionaea muscipula* Ellis), yellow pitcherplant (*Sarracenia flava* L.) and pink sundew (*Drosera capillaries* Poir) in addition to state-listed plant species and federal plant species of concern.

State and Federally Listed Plant Species

Parnassia caroliniana Michx. (Carolina grass of Parnassus)	NC Endangered
Solidago verna M.A. Curtis (springflowering goldenrod)	NC Threatened
Macbridea caroliniana (Walt.) Blake (Carolina birds-in-a-nest or bogmint)	NC Threatened and Federal Species of Concern

Partners

The park staff is small so it was critical to involve a number of partners in the project. These partners include the National Park Service's Water Resources Division (WRD), the Environmental Protection Agency (EPA), NC Natural Heritage Program, NC Department of Environment and Natural Resources, The Nature Conservancy (TNC), North Carolina Forest Service, Southeastern Community College (SCC) and many citizen-volunteers. With 25,000 plants to be added to the savanna, SCC and citizen volunteers carried out the majority of grass planting.

Establishing Baseline Hydrology - Well Installation and Mapping

In 1996, working with the NPS Water Resources Division (WRD), 14 ground-water observation wells and two surface-water staff gauges were installed in the savanna for a four-year study to monitor site hydrology under current conditions to allow for comparison with future conditions.

Holes were hand-augered to a depth of 4 to 5 feet and backfilled with about 3 to 4 inches medium sand. Two-inch diameter PVC pipes were slotted in the lower 18 inches, wrapped with shop cloth over the slots, and inserted in the holes. The void spaces outside the pipes were then backfilled with mixtures of sand from the augered material and bagged sand provided by the park. The wells were flushed of any foreign material by pouring water in until they ran clear, and were then allowed to equilibrate with the water table. The surface water gauges consisted of wooden stakes driven 2 to 3 feet into the ditch substrate. Elevations of the tops of all the wells and surface water gauges were surveyed to allow conversion of water level measurements to a common datum. Park staff recorded well-readings bi-weekly and transmitted the data to WRD for data entry, verification and analysis. Elevation data was taken along 12 transects through the savanna to create a topographic map of the site. These data included 440 ground points, location and elevation of the 14 wells, location and configuration of the ditch, and the approximate location of the historic drain system (Wagner and Martin 1997).

In 1997, WRD completed an assessment of existing vegetation conditions, including a map of plant communities, locations of rare species, and identification of relic savanna/pocosin species. From this data, WRD developed recommendations for a prescribed fire regime to control invasive weeds and encourage recovery of native savanna plant species. They also proposed a means to temporarily block the existing drainage system to simulate its removal. The existing wells would continue to provide hydrologic data for subsequent evaluation (Wagner et al. 1997), (Pelej 1997).

Natural Drainage Restoration

Since 1959, parking area storm water run-off was directed to the historic ditch cut through the center of the savanna. Following receipt of a 401 Water Quality Certification permit in 1998, park staff installed approximately 300' of new drain line outside the savanna, re-routing the run-off to an existing ditch system well below the savanna's natural drainage. Bentonite clay was then used to plug the lower end of the savanna ditch. Well readings continued to provide data for the next 2 years. When analyzed, results showed that water table levels in the post restoration period were generally higher and more stable than in the pre-restoration period (Woods and Wagner 2001).

In mid-summer1999, TNC conducted vegetation monitoring fieldwork establishing monitoring protocols and making management recommendations. In September 1999 Hurricane Floyd hit the park, flooding the savanna for more than 30 days, effectively delaying sweet gum and blackberry growth for several years.

In 2000, TNC published their report with the following four recommendations:

- Conduct an initial fall burn to be followed by planting nursery stock bunchgrasses - *Aristida stricta* (wiregrass), *Muhlenbergia expansa* (savanna muhly), *Sporobolus pinetorum* (Carolina dropseed), *Ctenium aromaticum* (toothache grass).
- After planting, when bunchgrass basal diameter is at least 3 inches or after one to two growing seasons, burn in the spring or late summer.
- Use prescribed burns on a 3-year cycle for the next 9-12 years.
- Refrain from mowing the upper portions of the slope from mid-March to November.

As a result of the report, funding was requested and obtained for growing and delivering the grasses and providing consultation in planting them. (Crichton and Sutter 2000).

Fire Management Compliance

The park's last prescribed fire had occurred in 1992 with NPS prescribed burning requirements changing dramatically in the intervening years. In 2001 park staff began work on a Fire Management Plan and Environmental Assessment, but eventually shifted fire plan work to the NPS Southeast Regional Office and contracted-out the EA.

Initial Seed Collection

In fall 2002, park staff concentrated on gathering adequate seed quantities of the TNC study recommended species. First, park staff met with NC Heritage Area Botanist Richard Leblond on a site visit to the Green Swamp, about 40 miles away from the park, to learn to identify the bunchgrass species needed and began seed collection. The TNC had no experience with nursery grown grasses and consequently could provide little relevant advice regarding optimum seed harvest times or collection techniques. Park staff and volunteers

collected 10 large brown grocery bags with seed heads of three of the four species. *Sporobolus pinetorum* proved true to its common name, Carolina dropseed, with individual seeds shattering as soon as they ripened, making seed harvest impractical.

Developing a Scope of Work, Selecting a Grower, Establishing a Contract

A search of qualified growers was conducted with four specialty nurseries inspected. On the basis of nursery visits and grower experience, a sole source contract was awarded to Terry Schultz at Carolina Greenery (CG) to grow, deliver, and supervise the planting of 25,000 grass plants, providing a combination of the bunchgrass species.

The NPS was to provide the seeds to the contractor in paper bags labeled by species. The contractor was responsible for subsequent storage, handling, viability/germination testing, propagation, care, and delivery of plants. Seeds were to be grown in sterile topsoil to avoid introduction of unintentional species. Tray cells were to be between 4.5 and 5 inches deep with plants fully grown-out prior to delivery. The contractor was also to provide consulting services regarding planting layout and protocols.

Established as a two-year contract, it allowed for the variables of seed availability, germination rates, climactic events (hurricanes and flooding in the MOCR savanna), and window of opportunity for prescribed fire in the savanna.

When the seeds collected from the Green Swamp in 2002 were delivered to the contractor, the park learned that roughly five to six times more seed would be needed to assure 25,000 plants. Subsequent germination rates proved low for these seeds as well, increasing the need for more seed. A contract extension was required since the park would have to wait until fall 2003 to collect additional seeds for plants to be installed in 2004.

The contractor agreed to provide training in recognizing seed ripeness, collecting techniques and storage from the time of collection to delivery to her. Seed collection was attempted in early fall 2003 on TNC lands in the Green Swamp with limited success. While the plants were abundant, few seed heads of any species were found. Bunchgrasses produce the greatest seed quantities in the fall following a hot, late spring burn (April-early June). Since few seeds were available from TNC lands, the park located plots in the North Carolina's Holly Shelter Game Lands that contained the needed species and had received late spring burns. Park staff and volunteers collected seeds from October through December. While seeds from wiregrass and toothache grass were relatively abundant, few savanna muhly plants produced seed heads at any location visited. No Carolina dropseed seeds were collected.

Prescribed Burning

The park's Fire Management Plan and EA/FONSI were completed in September 2003 along with a Prescribed Burn Plan for the savanna. No cutting or mowing had taken place in the savanna since 1998 and the over abundance of wet, green fuels now posed a problem. A test burn in October 2003 by the North Carolina Forest Service failed to ignite at a level adequate to kill the pines or knock back the sweet gum. After consultation with the Heritage Area Botanist and the contractor, the savanna was bush-hogged with the exception of the areas containing the *Parnassia caroliniana* and *Macbridea caroliniana*. After allowing the downed vegetation to dry for several weeks, a successful burn of the entire savanna occurred in November. All of the immature loblollies were killed and while the sweet gum was knocked back, the dense root systems remained, posing a serious challenge to bunchgrass planting.

Since, little is known about *Macbridea caroliniana's* reaction to fire; Heritage Area Botanist Richard Leblond request that two 1-meter plots with abundant populations be selected prior to burning with one to remain unburned. Stem counts were taken before burning and again the following summer, when new plants emerged. Average stem count for the two plots before the burn on August 25, 2003 was 115 and 144 on August 4, 2004. This limited data seems to indicate that a fall or winter burn may be helpful for this plant.

Grass Planting

While the contract stated individual plants, our contractor maintained that that true to name, bunchgrasses are more successful when three or more plants are grown in a plug. In December, 2003, 5400+ *Aristida stricta* plants (1800 plugs) were delivered. The plugs showed excellent root growth with all plugs fully filled out and each plug had at least three plants, with most containing 5 or more plants. Grass plugs with fully filled out root systems should not have the root system disturbed or broken up in any way even though they appear "root bound" when removed from the growing tray.

The contractor flagged specific "islands" to be planted, avoiding the dense mats of sweet gum roots. *Aristida stricta* is more successful in the drier locations of the savanna. The contractor tested soil moistness by removing soil plugs and checked for moisture visually and by compressing the soil by hand.

The contractor trained volunteers in proper planting techniques including how to properly remove plugs from the trays, proper planting spacing, correct planting depth, and how to use both types of dibble bars to ensure that no air pockets occurred around the roots.

Volunteers worked in teams of 3: one to "kick out" the debris on top of the soil and dibble a hole for planting, one to insert the plug and one to use the flat dibble to snug the soil up to the plug and then "heel in" the dibble hole. Plugs were spaced 24" apart and planted in off-set rows. The park provided the dibble bars and 24" dowels to use for spacing. It took approximately 5 hours for 11 volunteers to complete the work.

Plant delivery and planting continued in 2004, with 3600+ *Ctenium aromaticum* and 2700+ *Aristida stricta* plants installed. With each delivery, the contractor flagged specific planting areas and trained new volunteers. Soils were field tested with toothache grass needing a wetter habitat than the wiregrass. Of the *Ctenium* planted in June, a number of plants bloomed and set seeds by October. Wiregrass planted in 2003 also showed seed heads but suffered from shading by sweet gum shrubs. No prescribed burns took place in 2004, allowing planted grasses time to establish. This also allowed the sweet gum and briars to flourish. It became clear that additional work was needed to control the invasive species. Hand clearing of sweet gums and briars took place twice in the bunchgrass planted areas during the growing season.

While a growing season burn is more effective in controlling sweet gum, an April 2005 burn was largely unsuccessful given the extremely wet conditions in the savanna at the time of the burn. Nonetheless, four more plantings (April, June, August, and September) took place, installing 8256+ *Aristida stricta* and 5148+ *Ctenium aromaticum* plants. In all cases, the areas to be planted were cleared using a heavy-duty mower one day prior to planting.

A total of 16,056+ *Aristida stricta* and 8,748+ *Ctenium aromaticum* plants were installed for a total of 25,104 plants. However, 95% of all plugs contained at least 4 plants, not 3 which was used as the contract multiplier, so the actual number of plants is closer to 29,000. The savanna muhly seeds proved equally difficult to collect, exhibiting the same

characteristic as Carolina dropseed of immediately dropping ripe seeds. Ultimately, no *Sporobolus pinetorum* or *Muhlenbergia expansa* plants were grown or introduced.

New Monitoring Protocols

The vegetation monitoring protocols established by the TNC study proved too complex for use by the park. With guidance from Richard Leblond, park staff carried out stem counts for the Carolina birds-in-a-nest (bogmint) and springflowering goldenrod. Contractor Terry Schultz designed a simple monitoring plan to track the success of the bunchgrasses. Randomly placed circular monitoring plots will be used to track bunchgrass survival. Plants will be counted in plots immediately after planting to establish a baseline number to be compared to future counts of plant survival. Plots will have a 10 foot radius and the number of plots used will be sufficient to provide a 15% inventory survival count of planted plugs. Counting protocol will involve rotating a 10' measuring tape 360 degrees around each plot's center point, while conducting a complete count of all plants within the plot. (Schultz 2005)

Future Monitoring

Bunchgrass monitoring needs to be performed before the next prescribed fire which should occur between November 2006 and February 2007. While many of the plants appear healthy and are blooming, it is impossible to know the survival rate until monitoring occurs.

Conclusions

This project has been successful, but the work accomplished can only be maintained by regular, periodic prescribed burns in order to control the sweet gum and briars which will quickly overtake the area if permitted.

Sporobolus pinetorum and *Muhlenbergia expansa* seeds are poor candidates for wild seed collection for nursery grown stock. It is nearly impossible to collect a sizeable quantity of the seeds in the wild.

Macbridea caroliniana appears fire tolerant and seems to thrive when competing species are knocked back by a dormant season fire. *Solidago verna* has increased from 9 plants in 2001 to 61 plants in 2006. *Parnassia caroliniana* appears stable and now grows in two locations in the savanna instead of one, but no plant counts have occurred.

For this project to be repeated successfully elsewhere the following must be considered:

- existence of nearby locations with healthy bunchgrass populations that are periodically burned
- access to those lands for seed collection
- availability of trained staff to collect the seed
- availability of staff or volunteers to plant the plugs
- ability to locate a grower with considerable experience with the species to be grown
- ability to develop a flexible contract to allow for variables in seed collection amounts, germination rates, and natural phenomena such as hurricanes
- ability to carry out a prescribed burn when needed
- management desire to follow through with myriad details over a period of ten years

A project of this nature, in a small park with a small staff possessing little natural resources training, can be successful with consistent guidance from natural resources professionals, a reliable contractor, good community relations and park management's interest in following through with all aspects of the project.

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Environmental Factors Critical to the Reintroduction and Establishment of *Arundinaria gigantea* Canebrakes

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River cane (*Arundinaria gigantea* [Walt.] Muhl.) once formed vast monospecific canebrakes and was a dominant southeastern United States ecosystem. Decline of this ecosystem impacted many faunal species dependent on canebrake habitat, reducing biodiversity. Canebrake loss may have deleteriously affected ecosystem services, such as erosion control and nutrient filtration. Expansion of existing populations, as well as additional plantings, may serve to reestablish populations of river cane, but success requires understanding critical environmental parameters. The goal of this research is to identify light, moisture, and nutrient levels that are key for establishment. Greenhouse and field experiments have tested varying levels of these factors. Seedlings were grown under different light conditions (full sun to shade) in the greenhouse with leaf number and shoot and root length measured. Results indicated river cane seedling growth increased under full light conditions. In a field experiment, plots were set up along transects through existing cane populations. Trees were girdled and treated with herbicide to reduce forest canopy in treatment plots and growth compared to untreated plots. Results indicated canopy reduction increased new shoot growth. Seedling response to varying levels of moisture simulating drought, periodic flooding, and moist, well-drained conditions was measured by comparing shoot and root length and leaf number. Results indicated seedlings grow best in moist, well-drained conditions. In field experiments using transplanted river cane, plants grew better with complete nutrient fertilizer and phosphate supplementation. These results indicate management practices for successful expansion of existing canebrakes should include 1) reduction of canopy, 2) water, and 3) nutrient supplementation.

Key words: *Arundinaria gigantea*, canebrake, restoration, river cane

Native Vegetation Restoration in Existing Timber Stands

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Restoring native vegetation to the ground cover component of existing timber stands can sustain land productivity by conserving natural resources and providing an array of marketable commodities. Establishment and management of native ground cover vegetation alters surface water flow patterns and increases water soil infiltration rates resulting in reduced soil erosion and enhanced water quality. In addition, a vigorous native vegetation ground cover, which can be maintained with very little nutrient supplementation, could enhance livestock forage potential, improve wildlife habitat, and create a carbon sink for biofuel production and soil carbon sequestration.

Establishment cost and restorative value of a native vegetation community were evaluated in a recently thinned naturally regenerated 20-year-old loblolly pine (*Pinus taeda* L.*)* stand. Native vegetation treatments include two seedbed preparation methods and four vegetation communities. Experimental design was a randomized complete block with eight treatment plots and three replications. An intermediate harvest reduced existing pine stocking density from 350 trees per acre to approximately100 trees per acre. Native vegetation establishment was initiated on March 1, 2001 and completed on April 11, 2001. Seedbed preparation methods included a mechanical treatment that combined logging debris dispersal, double pass light disking, pre-seedling culti-packing, broadcast seeding and post-seedling culti-packing, and this mechanical treatment with a chemical brush and weed suppression. Native vegetation communities included single species broadcast seeding at 10 lbs of pure live seed per acre of 'Alamo' switchgrass *(Panicum virgatum*L.), 'Lometa' indiangrass (*Sorghastrum nutans* L.) and 'Kaw' big bluestem (*Andropogon gerardii* Vitman), and a 1-1-1 ratio three species mixture at the same rate. After the establishment growing season, all treatment plots were burned annually in April from 2002 to 2005. During February of 2004 and 2005, biomass and soil carbon samples were collected, and tree growth has been monitored since March 2001.

The biomass harvest was completed following the translocation of stem nutrients to the roots and dry biomass yield averages for Switchgrass and indiangrass were 7,000 and 3,700 lbs pr acre, respectively. Big Bluestem was negligible and its abundance was still widely scattered after four growing seasons. Root mass in the surface soil increased significantly in the switchgrass treatments. Annual burning without biomass removal severally damaged pine crowns in the switchgrass treatments resulting in 5 to 10% mortality rate. Establishing switchgrass in young pine plantations could create a carbon sink capable of annually accumulating 14,000 lbs of dry biomass per acre.

Key words: Big bluestem, indiangrass, loblolly pine, switchgrass

Landscape Scale Tools and Obstacles to Native Grassland Restoration

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Restoring native grasslands depends on management practices within the grassland itself, such as invasive species control or adding plant species. We can enhance these efforts by addressing landscape attributes of these systems. Planners must apply landscape ecology principles, including the dynamics of matrix and patch systems and the movement of organisms, to corridor and protected area design and conservation strategies. Managers must incorporate processes such as fire, flooding and herbivory, and natural range of variation, into resource management goals and practices. Scientists are increasingly using remote sensing and GIS-based tools to analyze, rather than describe, spatial and temporal events and threats. Although formal programs for landscape level work are limited, agencies are developing tools and case studies to achieve this end. Particularly relevant to grasslands are interagency fire program tools to characterize the dynamics of early seral stages of vegetation and enhancement of standard fuel models. The National Park Service (NPS), with numerous federal, state and private partners, has completed a pilot study to use regional conservation frameworks and geo-spatial data to identify opportunities for joint management of shared resources and threats. As a part of this project, partners have formed a network to evaluate native grasslands and their plant material needs. Numerous obstacles remain to any consistent and coordinated approaches to landscape scale work. Federal agencies are restricted in how they can apply resources outside of their respective land units. Legislative directives to protect ecosystems and processes are absent or obtuse. Disparate Agency missions lead to inconsistent standards and applications for restoration. Managers of rural, working landscapes lack financial incentives to cooperate with protected areas goals. With these in mind, I will provide suggestions for a framework to incorporate landscape concepts into northeastern grassland conservation and restoration.

Key words: Fire, grassland conservation, grassland restoration, spatial patterns

Coastal Native Grass Technology Development

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Abstract

The USDA, Natural Resources Conservation Service and its cooperators have developed native grass technology for restoring coastal dune and marsh communities over the past forty years. This technology includes methods for propagating the grasses in cultivation, processing vegetative plant material and seed, and establishing them on restoration sites in the field. It also includes the development of regional cultivars capable of tolerating environmental extremes and producing dependable quantities of quality seed and vegetative plant material. The establishment techniques and cultivars vary from north to south with different species and cultivars playing different roles in the different regions.

Key words: American beachgrass, bitter panicgrass, coastal panicgrass, saltmeadow cordgrass,

American Beachgrass (*Ammophila breviligulata* Fern.)
Function: quick erosion control on frontal dunes with active erosion and sand accumulation, declines when there is no sand deposition

Geographic Range: North and Mid-Atlantic Coast, Great Lakes

Propagation: division of plant

Field Establishment: primarily bareroot planting of divided culms, (2 culms per planting hole), also containerized plants

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars: (date cultivar was released for commercial production) - adaptation:
Cape (1970) – North Atlantic and Great Lakes Coasts
Hatteras (1969) – Mid- Atlantic Coast

Bitter Panicgrass (*Panicum amarum* Ell.)
Function: quick erosion control on frontal dunes with active erosion and sand accumulation, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: cuttings of stolons (seed stalks), division of plant

Field Establishment: primarily containerized plants, also bareroot planting and stolon planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars: (date cultivar was released for commercial production) - adaptation:
Northpa (1992) – Mid-Atlantic Coast
Southpa (1992) – South Atlantic and Eastern Gulf Coast
Fourchon (1998) – Western Gulf Coast

Coastal Panicgrass (*Panicum amarum var. amarulum* (A.S. Hitchc.&Chase) P.G. Palmer)
Function: quick erosion control on frontal dunes with active erosion and sand accumulation, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast

Propagation: primarily seed, also division of plant

Field Establishment: primarily containerized plants, also bareroot planting and seeding

Spacing of Planting: seed at 15 pounds of pure live seed per acre, plants 12-36 inches between plants and rows, typically 18 inches

Cultivars:(date cultivar was released for commercial production) - adaptation:
Atlantic (1981) – North, Middle, and South-Atlantic Coast

Seaoats (*Uniola paniculata* L.)
Function: long term dune stabilization, persists when there is no sand deposition

Geographic Range: Middle and South Atlantic Coast, Gulf Coast

Propagation: primarily seed, also division of plant

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar: (date cultivar was released for commercial production) - adaptation:
Caminada (2001) – Western Gulf Coast

Saltmeadow or Marsh Hay Cordgrass (*Spartina patens* (Ait.) Muhl.)
Function: long term stabilization of back dunes and salt marshes above high tide line, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: division of plant

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar:(date cultivar was released for commercial production) - adaptation:
Avalon (1986) – North Atlantic Coast
Flageo (1990) – Middle and South Atlantic Coast, Gulf Coast
Sharp (1994) – South Atlantic Coast, Gulf Coast
Gulf Coast (2003) – Western Gulf Coast

Seashore Paspalum (*Paspalum vaginatum* Sw.)
Function: long term stabilization of back dunes and salt marshes above high tide line, persists when there is no sand deposition

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: division of plant, creeping stolons

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivars: (date cultivar was released for commercial production) - adaptation:
Brazoria (1999) – Western Gulf Coast

Smooth Cordgrass (*Spartina alterniflora* Loisel.)
Function: long term stabilization of salt marshes below high tide line

Geographic Range: North, Middle, and South Atlantic Coast, Gulf Coast

Propagation: primarily seeds, division of plant

Field Establishment: primarily containerized plants, also bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar: date cultivar was released for commercial production) - adaptation:
Bayshore (1992) – North Atlantic Coast
Vermilion (1989) – Western Gulf Coast

Giant Cutgrass (*Zizaniopsis miliacea a* (Michx.) Doell & Aschers.)
Function: long term stabilization of freshwater marshes and shorelines with water up to 3 feet deep

Geographic Range: Middle and South Atlantic Coast, Gulf Coast

Propagation: stolons (seed stalks), division of plant

Field Establishment: stolons, containerized plants, bareroot planting

Spacing of Planting: 12-36 inches between plants and rows, typically 18 inches

Cultivar: (date cultivar was released for commercial production) - adaptation:
Wetlander (1993) – South Atlantic and Gulf Coast

Maidencane (*Panicum hemitomon* J.A. Schultes)
Function: long term stabilization of freshwater marshes and shorelines with water up to a foot deep

Geographic Range: Middle and South Atlantic Coast, Gulf Coast

Propagation: rhizomes (underground runners), division of plant

Field Establishment: rhizomes, containerized plants, bareroot planting

Spacing of Planting: rhizomes in continuous trenches one inch deep and one foot apart, plants 12-36 inches between plants and rows, typically 18 inches

Cultivars: (date cultivar was released for commercial production) - adaptation:
Halifax (1974) – Middle and South Atlantic Coast
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The History of Native Grass Technology Development

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Abstract

Native grasses are conservation tools that are used routinely in today's world. Establishing and managing those grasses has evolved over the last 60 years to the present opportunities that exist today. The development of technology in management of the grasses in the field, establishment, cultivar development and ecotype selection, seed harvesting and cleaning, seed production, improved equipment design, and the development of weed management strategies has contributed to those opportunities.

Key words: Cultivar development, equipment, establishment, seed production

Introduction

Today we have the opportunity to establish native grass stands throughout the eastern half of the country with confidence that we can buy the species that we need, sow or plant grasses with the proper seeding rates and plant spacings, and manage them to maintain a healthy stand. That ability has not come overnight. A mere 60 years ago there were no cultivars. Twenty years ago there were no drills that could sow chaffy seeds or seed cleaners that could clean them. Only in the last decade has there been a wide range of cultivars and local ecotypes from the East and more than one seed grower to produce them. The evolution of this technology has been very recent.

I will discuss that evolution in terms of management of the grasses in the field, establishment technology, cultivar development and ecotype selection, seed harvesting and cleaning, seed production, improved equipment design, and the development of weed management strategies.

Management of Native Grasses

Managing native grasslands has many facets. Managing inland prairies is quite different from managing coastal dunes and marshes. Managing forages for livestock requires different knowledge than managing grasses on reclaimed mines does.

The effects of natural forces and management on inland prairies were first observed by Native Americans, especially following fire started by lightning. That observational knowledge was first studied in structured research by Midwestern universities, government agencies, and non-government organizations. More recently eastern universities, government agencies, and non-government organizations have begun to study natural grasslands such as serpentine barrens, piedmont prairies, and canebrakes.

Southern coastal grasslands in the east were studied extensively by Seneca, Woodhouse, and Broome from North Carolina State University in the 60's and 70's. Northeastern dunes got the attention of John Zak at the University of Massachusetts and the USDA, Natural Resources Conservation Service (NRCS) at the Cape May Plant Materials Center (PMC) in New Jersey.

The first management technology for forage production was conducted in the Midwest in the 40's. In the Northeast Jerry Jung of the USDA, Agricultural Research Service (ARS) at University Park, PA and Doug Perry with ARS in West Virginia studied forage production in the 70's and 80's. Jerry Jung continued his work through the 90's with Dave Belesky of ARS in West Virginia. Today Matt Sanderson continues the work with ARS at University Park. The Big Flats, New York PMC of the USDA, NRCS, also conducted early forage research. The management criteria developed for the Midwest was tested using eastern cultivars under eastern climatic and soils conditions. Research topics included duration, height, and frequency of grazing and hay harvest, fertilizer and lime requirements, and pesticide needs and effectiveness. A major development was the introduction of no-till technology with the correct seeding rates for the Northeast and effective fertilizer and pesticide application technology.

The historic mine reclamation research was conducted by Roy Blaser at Virginia Tech, William Platt at West Virginia University, Guy McKee at Penn State University, and Don Henry of USDA, NRCS in Kentucky in the 60's and 70's. The more recent mine reclamation research is being conducted at Virginia Tech and West Virginia University. The Big Flats, New York PMC also conducted early reclamation research and field testing.

Establishment Technology

Researchers adapted establishment technology from the Midwest to conditions in the East. The higher precipitation and humidity, shallow acid soils, droughty and saturated conditions, and high populations of weeds, insects, and diseases all pose challenges to establishment. Jerry Jung of the USDA, ARS at University Park, PA and Doug Perry with ARS in West Virginia were heavily involved in developing that technology as was the Big Flats, New York PMC. Research topics included seeding rates, seeding dates, seeding depths, fertilizer and lime rates and timing, and the effectiveness of pesticide application.

Cultivar Development

The use of native grasses for restoration, coastal revegetation, forage production, or mine reclamation would not be possible without the seed and planting stock we use to establish the stands. To encourage commercial production of native species government agencies and universities develop cultivars of the species with known ranges of adaptation.

'Blackwell' switchgrass (*Panicum virgatum* L.) was the first native grass cultivar released to the commercial seed trade. It was released in 1944 from the Manhattan, Kansas PMC and Kansas State University. It was originally collected in northern Oklahoma in plant hardiness zone (PHZ) 7 and was used extensively throughout the East until better adapted cultivars were developed.

'Cave-in-Rock' switchgrass was released in 1974 by the Elsberry, Missouri PMC. It was collected in Illinois in PHZ 5 and was a better forage type than 'Blackwell' for the Northeast. 'Alamo' Switchgrass was released in 1978 by the Knox City, Texas PMC. It was collected in Texas in PHZ 9 and is well adapted to Southeast. 'Shelter' Switchgrass was released in 1987 by the Big Flats, New York PMC. It was from West Virginia PHZ 6 and is a very good switchgrass for wildlife habitat for Northeast. 'Shawnee' Switchgrass was released in 1995 by the Agricultural Research Service (ARS) in Lincoln, Nebraska. It was a selection from 'Cave-in-Rock' and is an improved forage switchgrass for Northeast.

'Kaw' big bluestem (*Androgpogon gerardii* Vitman) was released in 1950 by the Manhattan, Kansas PMC. 'Kaw' was from Kansas in PHZ 5. It was the first release of a big bluestem and is adapted to Northeast. 'Roundtree' big bluestem was released in 1983 by the Elsberry, Missouri PMC. Its origin was Iowa PHZ 5. It was better adapted to Northeast than 'Kaw'. 'Niagara' big bluestem was released in 1986 by the Big Flats, New York PMC. It was from New York in PHZ 6 and was the first big bluestem released that was from the Northeast.

Cheyenne' indiangrass [*Sorghastrum nutans*(L.) Nash] was released in 1945 by the Manhattan, Kansas PMC. It was originally collected in Oklahoma in PHZ 6. It was the first release of an indiangrass and was adapted to Northeast. 'Osage' indiangrass was released in 1966 by the Kansas Agricultural Experiment Station. It was also from Oklahoma in PHZ 6 and was adapted to Northeast. 'Lometa' indiangrass was released in 1981 by Knox City, Texas PMC. It was from Texas and PHZ 7 and was the better adapted to Southeast than other cultivars. 'Rumsey' indiangrass was released in 1983 by the Elsberry, Missouri PMC. It was collected from Iowa in PHZ 5. 'Rumsey' is better adapted to the Northeast than other cultivars.

'Tioga' deertongue [*Dicanthelium clandestinum* (L.) Gould] was released in 1975 by the Big Flats, New York PMC. It was from Pennsylvania in PHZ 5. It was the first cultivar selected specifically for coalmine reclamation and is adapted to Northeast. 'Cape' American beachgrass was released in 1970 by the Cape May, New Jersey, PMC. It was from Massachusetts and PHZ 7. It was the first cultivar selected for coastal dune revegetation and is adapted to the North Atlantic Coast. 'Atlantic' coastal panicgrass was released in 1981 by the Cape May, New Jersey PMC. It was collected in Virginia and PHZ 7. 'Atlantic' was the first cultivar for coastal dune revegetation that can be propagated by seed. It is adapted to the eastern Atlantic Coast and has been used for wildlife habitat improvement on inland sites.

Seed Production

Cultivar development would mean nothing if there were no commercial growers of seed and nursery stock to supply the public. Since the native grasslands were more prevalent in the Midwest and the first cultivars were from the Midwest and well adapted to the Midwest, the first and still the largest seed growers are in the Midwest. Douglass W. King Seed Company started in Texas in 1912, the Bamert Seed Company began in Texas in 1951, Stock Seed Farm was started in Nebraska in 1956, Sharp Seed Company was founded in Missouri in 1958, and Pogue Seed Company started in Texas in 1960. Ernst Conservation Seeds began operation in Pennsylvania in 1960. These seed companies still provide most of the seed of species adapted to the East.

Improved Equipment Design

The role of seed drills in native grass establishment is critical. Native grasses are not vigorous as seedlings and drilling the seed into the soil at specified depths is very important to establishing a stand. Regular agricultural drills were well suited to sowing smooth seeds such as switchgrass. Chaffy seeds such as big and little bluestem [*Schizachyrium scoparium* (Michx.) Nash] and indiangrass required mixing with inert substances such as lime, sawdust, or peanut hulls to flow through the drill. In 1974, the Truax Company developed a chaffy seed drill. In 1979, Harold Wiedemann, a researcher at Texas A&M University, developed a metering system for chaffy seed. These developments allowed seed to be sown without mixing.

Harvesting and cleaning chaffy seeds have also poses great difficulties for the industry. Early researchers, restorationists, and seed growers used wheel driven seed strippers pulled behind tractors to harvest native seeds. In the 1990's the Flail Vac Seed Harvester was developed. The Flail Vac could be mounted on the front of a tractor using front end loader mounting brackets and hydraulics and harvest seed without first trampling it. Chet DeWald of the Agricultural Research Service in Woodward, Oklahoma and Victor Beisel of Fargo, Oklahoma developed a series of machines to clean chaffy seed throughout the 80's and 90's and into the new millennium.

Weed Management

Weed management has been a persistent problem in native grass establishment and management. For most of the past 60 years, native grass establishment relied on thorough tillage, good weed control before sowing the seed or planting the nursery stock, and cultural strategies such as grazing weeds close or mowing the seed heads off of annual weeds before seed matured. The advent of no-till establishment of native grasses facilitated a significant increase in stand success, especially when introducing native grasses into stands of exotic forage grasses. .Broadleaf weed herbicides provided good control of both annual and perennial broadleaf weeds. For a brief period, atrazine was labeled for control of weeds before they emerged. The recent development of pre-emergent pesticides such as Plateau has provided valuable tools for integrated weed management. The combination of cultural, mechanical, and chemical weed management tools makes native grasses much easier to establish and maintain than it was even ten years ago.

The accumulated developments in native grass technology over the past 60 years have all contributed to our ability to restore grassland ecosystems, provide native grass forage for livestock, and reclaim disturbed landscapes with native vegetation.

Cultural Landscape Management at Stones River National Battlefield: Preservation of Civil War Era Earthworks with Native Warm-Season Grasses

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Through vegetation monitoring conducted in 2000, 2001, and 2006, Stones River National Battlefield staff demonstrated the success of planting native grasses on the earthworks of Fortress Rosecrans. The earthen fort was engulfed in invasive exotic species when the park acquired the site in 1993. At that time, park staff began to implement a plan to preserve and interpret the earthworks, which are considered both historic structures and components of a cultural landscape. This involved cutting woody species from the area and treating invasive species and resprouts with herbicides. Then we planted native warm-season grasses via seed, plugs, and rootstock. Park staff selected these species to revegetate the earthworks because they have extensive root systems to stabilize the structures and are adapted to the hot, often dry conditions and low nutrient soils of middle Tennessee. They require less maintenance once established which reduces the impact of human activity and concomitant degradation of the structures. To determine the effectiveness of the revegetation and exotic management efforts, park staff, monitored plots in spring and fall of 2000, 2001, and in the fall of 2006. The cultural resource division of the Southeast Region funded the development of the protocols along with the monitoring which have been included in an online earthworks management manual. Analysis of these data in 2002 show that native grass cover increased significantly within plots and native forbs increased as well. Unfortunately, an increase in invasive species and vines was also detected. This trend, however, is not statistically significant. Results of 2006 monitoring are not yet available. Park staff used the results of the 2002 data analysis to adjust management practices. Analysis of 2006 monitoring efforts will reveal whether changes made in management practices were effective in reducing invasive species' cover while continuing to support establishment of native plants.

Key words: Fortress Rosecrans, invasive species, National Park Service, revegetation

Restoration and Preservation of Stones River National Battlefield using Native Plants

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Abstract

In addition to safeguarding cultural and natural resources, all National Parks have a restoration mandate to return human-disturbed areas to natural conditions (USDI-NPS 2000). Because much of Stones River National Battlefield has been subjected to anthropogenic disturbance, the park staff is actively engaged in restoration and rehabilitation. Restoration work using native species began at Stones River National Battlefield with the revegetation of two Civil War era earthwork sites in 1994. We have since extended native plantings to other areas across the park, experimented with a variety of establishment and seed collection techniques, and established monitoring plots to determine the effectiveness of our planting efforts. We also continue to modify our plant establishment techniques throughout the park. Through these concerted efforts, we have greatly increased our ability to manage park land in a sustainable manner.

Key words: Cultural resource, National Park Service, native warm-season grasses, restoration

Introduction

The Battle of Stones River was fought between 31 December 1862 and 2 January 1863 in Rutherford County, Tennessee. It raged over a 4,000-acre area of which about 17% is preserved within Stones River National Battlefield (USDI-NPS 1998). The significance of the Battle of Stones River is widely recognized. It constitutes the first major battle in the Union's effort to divide the Confederacy by mounting an eastward moving campaign through the South to the Atlantic Ocean (Willett 1958). It resulted in the Union Army's occupation of Murfreesboro and control of productive agricultural land as well as control of a strategic supply network. This was a politically important Union victory that persuaded France and England to support the Union during the Civil War. Injury and loss of life were considerable over the three days of fighting. Of the 83,000 men who fought in this battle, 23,000 became casualties with the Union army suffering more casualties than during any other battle of the Civil War (USDI-NPS 1998).

Stones River National Cemetery, established in 1865, was the first area of the park to be officially sanctioned as a national memorial to those who fought in the Battle of Stones River. Through the creation of Stones River National Military Park in 1927, approximately 323 additional acres were acquired and preserved by the War Department bringing the total acreage to approximately 343 by 1934. The park was managed by the War Department until 1933 when the National Park Service took over its operation. Approximately 305 acres have been added to Stones River National Battlefield since the National Park Service acquired

stewardship responsibility. Of that approximately 305 acres, 71% has been acquired since 1995.

The battlefield has been drastically altered from its natural state and from the agricultural landscape of the 1860s. After the Civil War ended, an African American community grew up on the portion of the battlefield deemed to have seen the heaviest action during the Battle of Stones River. Forty-six properties within that community were slated for procurement by the War Department in 1928 (USDI-NPS 2004). After acquiring the tracts that composed the original Stones River National Military Park, domestic and agricultural structures determined to postdate the battle were removed (USDI-NPS 2004). Land was cleared and limestone boulders that characterize the middle Tennessee landscape were removed. Of the tracts purchased since 1995, parking lots were located on six, paved or unpaved driveways on 18, houses on 16 tracts, farm buildings on 12, businesses on five tracts, household dump sites currently occupy portions of four tracts, commercial dumpsites occupy portions of 5 tracts, and construction debris occupies sizeable portions of two tracts.

Other anthropogenic disturbance includes sites infested by invasive plant species and those from which the park's resources staff has removed invasive plants. Of the approximately 606 plant species documented from Stones River National Battlefield, about 170 are exotics. Of these 170 exotic plants, the Tennessee Exotic Pest Plant Council lists nineteen as severe threats to Tennessee's native plant communities. Twenty-four are listed as significant threats. Twelve are listed as lesser threats and 3 are on the watch list for Tennessee.

At Stones River National Battlefield, a natural resources program was created to compliment and support the preservation and improvement of the park's important historic resources using natural resource management techniques. This effort began in 1994 when park staff selected native warm-season grasses for restoration of the recently cleared Civil War era earthworks of Fortress Rosecrans. With the addition of professionals in the fields of botany, zoology, wildlife biology, and plant ecology, the natural resources program has strengthened. Planting efforts are being fine-tuned and the direction of landscape management is changing. This paper outlines restoration, rehabilitation, and preservation efforts conducted by natural resource management program staff from 1994 to the present at Stones River National Battlefield.

Managing earthworks with warm-season native grasses

Stones River National Battlefield staff selected native warm-season grasses to revegetate remnants of Fortress Rosecrans, a Civil War era earthen fortification, after removing woody and invasive vegetation (USDI-NPS 1991). Native grasses are ideal for preserving these historic earthen structures because their extensive root systems provide excellent erosion control. Native warm-season grasses are also adapted to the hot, dry conditions of middle Tennessee summers and they grow well in nutrient poor soils. For these reasons, native grasses require less management relative to turf grasses and offer a sustainable, low maintenance option. At the park, we have tested a variety of grass establishment methods which includes planting both seed and live plants.

Planting methods:

- Hand-seeding: useful for small scale planting; labor intensive, can cause significant disturbance to the slopes.
- "Spike," seeder made from a 50 gallon plastic drum that is lowered and raised via ropes from the top of the earthworks: reduces disturbance to slopes and safety hazards to employees, thoroughly plants slopes.
- Slurry, mixture of seed, potting soil, mushroom compost, mycorrhizal solution, and water: reduces disturbance to slopes and safety hazards to employees, includes essential nutrients in the planting mix; slurry dries and peels during dry times of the year.
- Straw blowing native hay and seed: efficient, reduces disturbance to slopes and safety hazards to employees; requires specialized equipment, however, equipment can be rented locally.
- Bare root plants and plant plugs: bypasses seed germination problems, provides immediate cover; labor intensive, expensive, can cause major disturbance to the slopes, may pose safety risks to employees working on slopes.
- Native turf: bypasses seed germination problems, provides immediate cover over large areas, reduces disturbance to slopes and safety hazards to employees; manually cutting turf has been labor intensive; however new techniques have improved this aspect of native turf use.

The native warm-season grasses that cover the earthworks are cut once a year in late June or early July. This accentuates the outline of the earthen walls facilitating their interpretation. Cutting the grasses at this time also gives the grasses enough time to produce viable seed. Portions of Fortress Rosecrans were burned in 2004, 2005, and 2006. These burns resulted in lush growth of the native warm-season grasses and appear to have increased cover of these species.

Restoration of disturbed lands-Native grass conversion

In May of 2004, the park staff began converting approximately 60 acres to native grasses. The converted area includes former crop fields that were planted in soybeans in 2003 (37 acres) and hay fields dominated by tall fescue (*Lolium arundinaceum* (Schreb.) S.J. Darbyshire) or infested by Johnson grass [*Sorghum halepense* (L.) Pers.], but, in most cases, possessing a native warm-season grass component (23 acres).

We planted native seed with a Truax Utility Series native seed drill (Truax Company, New Hope, MN) borrowed from the Tennessee Wildlife Resources Agency (TWRA) at 6 to 10 lb pure live seed per acre. Native seed planted by park staff included switch grass (*Panicum virgatum* L.), eastern gamagrass [*Tripsacum dactyloides* (L.) L.], Virginia wild rye (*Elymus virginicus* L.), Indiangrass [*Sorghastrum nutans* (L.) Nash], little bluestem (*Schizachyrium scoparium* Michx.), splitbeard bluestem (*Andropogon ternarius* Michx.), and Elliot's bluestem (*Andropogon gyrans* Ashe.). The park used seed collected on site, collected from middle Tennessee State Natural Areas, and we also purchased local ecotype seed from Roundstone Native Seed in Upton, Kentucky.

Crop field treatment included one or a combination of the following:

- Apply imazapic (Plateau) at 4-8 ounces per acre before and/or after planting (also applies to hay fields). Imazapic application must never exceed 12 ounces per acre (also applies to hay fields).
- Apply glyphosate (Accord Concentrate) at 2% solution to treat bermudagrass [*Cynodon dactylon* (L.) Pers.] before planting.
- Apply glyphosate at 1 to 2% solution plus imazapic at 4-8 ounces per acre before planting.
- Apply triclopyr (Garlon 4) to control broadleaf invasives at 2% solution before or after planting (also applies to hay fields),
- Cut or pull invasive annual species post planting.

Fields are maintained through periodic cutting and prescribed fire.

Local genotype seed

We are creating local genotype seed collection fields as a part of our continuing restoration efforts. The park began on a small-scale by hand-planting plugs that were grown from seed collected on the park. In 2003, we entered into an agreement with the Natural Resource Conservation Service (NRCS) Plant Materials Center in Alderson, West Virginia to grow plugs and produce seed from propagules of native species collected at Stones River National Battlefield. Since 2004, we have planted approximately 61,000 plant plugs representing 26 species of grasses, sedges, and forbs. We collected seed from our fields in 2004 and 2005 using a Native Prairie Seed Stripper Model 610 (Argyle Machine, Inc., Argyle Manitoba, Canada) borrowed from TWRA. We used this seed in our spring 2005 and 2006 planting efforts. In addition to fields on the park, NRCS will create fields of Stones River National Battlefield natives at the Alderson, West Virginia site from which seed can be collected for the park as needed.

Planting methods include:

- Hand-plant using bulb planters or a gas powered auger.
- Plant with a tobacco plug planter after plowing and disking.
- Plant with a tree planter in fields where we pre-treat competing vegetation with a 2% glyphosate solution or imazapic at 4-8 ounces per acre.

Other local genotype seed sources include native hay collected from inspected fields on site and from nearby farms. We also have an agreement with the Tennessee Department of Environment and Conservation's Division of Natural Heritage to collect seed from natural areas within the Central Basin. We have collected seed by hand, with a commercial lawn sweeper either pulled behind or mounted on the front of a Polaris Ranger, and with a Native Prairie Seed Stripper. NRCS cleans the seed for the park or the seed/chaff mix can be planted using a straw blower.

Monitoring

Data collected through monitoring aids us in fine-tuning our techniques and determining the effectiveness of our eradication and planting efforts. We monitor the earthworks using a protocol and permanent plots established in collaboration with The Nature Conservancy. Analysis of data (Bowen and Sutter 2003) collected in 2000 and 2001 revealed that establishment of native grasses was successful after 1 year; native forb cover also

increased; unfortunately, invasives increased as well (Sutter 2002). We also monitor sites where we treat exotics and plant natives using a standard line-intercept technique developed with the assistance of Dr. J. Walck, professor of Ecology at Middle Tennessee State University and GIS technology. In addition to these monitoring methods, we are examining results of annual breeding bird surveys to help inform us on the success of our native grass establishment on a larger scale across the park.

Summary

Stones River National Battlefield has come a long way since planting the first native grasses on the earthworks of Fortress Rosecrans. Although we continue to fine-tune our plant establishment techniques at the earthwork sites, we also use native grasses in all of our restoration and rehabilitation efforts. This includes revegetating former house sites, old agricultural fields, and sites where exotic invasive plants have been treated. In 1994, local genotype seed sources were not available to the park. We now restrict our planting to "local" genotype plant material which includes commercial sources in Kentucky and middle Tennessee. In time, the park will become less reliant on plant material from commercial sources as we expand our native hay and seed collection efforts within Rutherford County and continue to develop increase fields on site through a contract with the USDA-NRCS. Data collected through monitoring continues to inform our management program by providing feedback on the effects of different management techniques. Through these concerted efforts, we have greatly increased our ability to manage park land in a sustainable manner.

Acknowledgements

We would like to thank all those who have assisted us in our native plant work. The Tennessee Wildlife Resources Agency has been very helpful providing advise, assistance, supplies, and equipment. We particularly thank Russ Skoglund and Dick Conley for the time and effort they have given to our work. Thomas Hall of the Tennessee Forestry Division lent us a tree planter and demonstrated efficient planting techniques to Stones River National Battlefield natural resources program staff. The NRCS Plant Materials Center at Alderson, West Virginia made a plow and tobacco planter available to us and Dan Pinkham and Randall Lester provided us with fabulously healthy plant plugs. Also, we would like to thank our local NRCS District Conservationist, Larry Robeson, who has helped us plant and advised us over the past several years.

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Management and Restoration of Native Grasslands at Fort Indiantown Gap National Guard Training Center, Pennsylvania

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Fort Indiantown Gap National Guard Training Center (FIG-NGTC) is a 17,100 acre military training facility in south-central PA. The combination of 70 years of military training (soil disturbance and fire regime) and the absence of industrial agriculture has created a complex of grassland, scrubland, and forest habitat of differing soil types, succcessional ages, and complexities. Current projects include the restoration of low-quality grasslands using prescribed fire and selective herbicides for wildlife and soldier habitat, inventory and monitoring of biodiversity, PA-ecotype seed collection and propagation, development of native seed mixes for intensely-utilized training areas, and providing a source of PA-ecotype plant and animal grassland-dependant species for repatriation in other areas of Penn's Woods and the Mid-Atlantic. Authorized in 1931, the FIG-NGTC has 3,000 acres of grassland, scrubland or savanna, 2,000 acres of mowed fields with both native and exotic grasses, and 11,000 acres of forest. The warm-season species of grass [mainly little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and broomsedge (*Andropogon virginicus* L.)] are all PA-ecotype, with some introduced cool-season grasses from former pasture and land rehabilitation activities. Interspersed are native thistles and milkweeds, which are important nectar sources for butterflies. The only known viable population of regal fritillary (*Speyeria idalia*) butterfly east of Illinois occurs at FIG-NGTC. The butterfly larvae feed on leaves of arrow-leaved violet (*Viola sagittata* Ait.), which depends on disturbance for establishment and germination. More than 10 other species of rare grassland plant and animal species occur on the installation. FIG-NGTC partnered with Ernst Conservation Seeds to collect and propagate PA-ecotype little bluestem and indiangrass (*Sorghastrum nutans* L. Nash). In 2000, 2001, and 2003, 300-500 lbs of bulk little bluestem seed and small quantities of indiangrass were collected and processed. Propagation fields were established at Ernst's facility and seed was provided for planting 10 acres on target berms and 15 acres in a Landing Zone. A seedbank of native grass is present because large tank firing range (700 acres) was completed in 1998 and since then disturbed areas have come in as dense native grass stands, even though they were initially seeded with cool-season grass mixes for erosion control. Tree scar analysis revealed that some of the historical grassy areas burned every three years. Prescribed fire is now used to control fuel load and restore grassy areas and savanna habitat, which also benefits tactical military training exercises and regal fritillary habitat. The goal of FIG and all military installations is ecosystem sustainability, biodiversity conservation, habitat improvement and restoration, military training, and integrated land uses. Our objective is to develop a cost-effective monitoring program that provides real-world and scientifically-sound data to support the military training mission. Despite a public perception that military training degrades biodiversity, water quality, and the ecosystem, our work demonstrates that FIG-NGTC is a hotspot of biodiversity due to large patches of quality

habitat, fire regime, lack of industrial agriculture, and high-intensity, low-frequency disturbance.

Key words: Biodiversity, habitat restoration, military training lands, regal fritillary butterfly

The Use of Native Grasses, Sedges, and Forbs to Restore Fire Suppression Lines on Wayne National Forest

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Forest wildfires are a common occurrence in the spring and fall in southern Ohio. These fires are either caused by arson or escaped from private land owners burning debris. Between fall of 2005 and spring of 2006 the Ironton District of the Wayne National Forest responded to and suppressed more than 100 wildfires. On four of these fires a bulldozer was used to create fire breaks to stop the fire from advancing further. Two of these fires were used to test the effectiveness of planting native grasses, sedges and forbs for re-vegetation of the bulldozer lines. Re-vegetation of bulldozer lines is an important aspect of post-fire rehabilitation because bulldozer lines can lead to erosion problems on slopes and are prime locations for the establishment and spread of non-native invasive species. Sixteen different species of native plants (eleven grasses, one sedge and four forbs) were planted along the dozer lines of the two 2006 fires. This paper will discuss the methods used to rehabilitate these fire lines, the survival and fecundity of the plants that were used and the over all success of the plantings for invasion and erosion control.

Key words: Bulldozer lines, manmade fire, natural fire, post-fire rehabilitation

Lehigh Gap Restoration Project: Native Grasses Key to Remediation of Palmerton Superfund Site

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Abstract

The Lehigh Gap Wildlife Refuge, owned and operated by the Wildlife Information Center, Inc. is a 750–acre tract on the north slope of the Kittatinny Ridge in eastern Pennsylvania at Lehigh Gap, where the Lehigh River cuts through the ridge. The land is part of the 2-3,000-acre Palmerton Zinc Pile Superfund site, which was devastated by air pollution, erosion, and accumulation of heavy metals – the result of 80 years of zinc smelting in Palmerton. The Center is using native warm-season grasses as the key component of its efforts to restore a functioning ecosystem and valuable wildlife habitat on this barren mountainside. The mountain is moderately to steeply sloped and rocky, making it difficult to access or inaccessible to agricultural equipment. Applying what was learned by USDA-NRCS in reclaiming abandoned mine sites in the northeastern United States, the Wildlife Center, in conjunction with US EPA and the Superfund responsible party, Viacom, Inc., developed and implemented a restoration plan beginning in 2003 with 56 one-acre-test plots applied with land-based methods. Based on the success of those plots applied by land – based methods, and of aerial application on steep slopes, full scale planting of the refuge lands and private lands throughout the Superfund site is in progress in 2006.

Key words: Heavy metals, remediation, Superfund, warm-season grasses

Introduction

More than 2,000 acres of the Kittatinny Ridge (Blue Mountain) near Palmerton, Pennsylvania were deforested and contaminated with heavy metals during the 20th Century. Eighty years of zinc smelting in Palmerton is considered the primary cause of the ecological damage. Sulfur dioxide from coal burning is blamed for deforestation of the Kittatinny near the gap through which the Lehigh River flows. In addition, heavy metals (primarily zinc, cadmium, and lead) were deposited on the remaining soils, which are subsoils, exposed to the surface or covered with a veneer of rocks. In 1983, the site was added to the National Priorities List under the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), commonly referred to as the Superfund law. The Palmerton Superfund site includes several thousand acres of land on the Kittatinny plus other lands on an adjacent ridge called Stoney Ridge. The land on the Kittatinny is designated as Operable Unit 1 (OU1) in the Superfund process (U.S. EPA 2005). The OU1 area is mostly devoid of vegetation, and, in many places, the A and B soil horizons have eroded from the mountainside.

From 1991-95, the responsible parties and EPA utilized a revegetation method for about 900 acres that included bulldozing nearly 60 miles of dirt roads on the mountainside and

trucking in millions of tons of sewage sludge and fly ash to create an organic layer (Oyler 1988). Various grasses and tree seedlings were planted in the mixture. The site is mostly covered with vegetation, much of it non-native, and tree establishment and survival are lagging.

In 2002, the Wildlife Information Center (WIC) purchased 750 acres on the Kittatinny just west of Lehigh Gap, including about 350 acres within the Superfund zone that needed remediation. Not wanting to create roads that change the contours of the mountain, and wanting to work with nature to revegetate the site with native vegetation, the Center began researching methods that would mimic ecological processes rather than impose an engineered solution on the land. Since a variety of warm-season grasses (WSGs) were already growing on the periphery of the site, WIC saw them as a key to the reclamation of the site. Further research led WIC to the work of the USDA-NRCS in revegetating abandoned mine sites, which shared many characteristics with the site at Lehigh Gap. A partnership ensued with one of us (Dickerson of NRCS) becoming an advisor to the other (Kunkle of WIC) in the process of revegetating the lands of the Lehigh Gap Wildlife Refuge.

The Plant Materials Program of NRCS initiated a study of sand and gravel mine reclamation in 1975. The goal was to determine if long-term cover performance could be enhanced with species other than the commonly used introduced plant materials. Earlier work by the Plant Materials Program had established the utility of WSG species such as deertongue (*Dichanthelium clandestinum* (L.) Gould) and switchgrass (*Panicum virgatum* L.) on acid coal strip mines (USDA-SCS-PM Program Annual Technical Reports of the Big Flats Plant Materials Center).

The new effort involved plot plantings at 10 mines located from New York to Connecticut to Maine. The work was summarized by Gaffney and Dickerson (1987). That summary compared the relative performance of native WSGs with introduced cool-season grasses (CSGs) and several introduced legumes over a ten-year period. The WSGs consistently outperformed the CSGs and the legumes on sites with low soil fines (15% or less passing a 200 mesh sieve). Low fines were associated with low nutrient and water holding capacities. As mine sites with low fines are common this finding encouraged further study of the use of the native WSGs (Dickerson et al. 1989). Combined with the earlier findings on coal mines, a pattern of superior stress tolerance was established for that group of native grasses.

In the initial work, the effort had focused on a comparison of grass species. From the early 1980s to 1998, a comparison of WSG cultivars, species mixtures and establishment techniques was undertaken. Replicated plots and much larger test plantings were utilized, predominantly in NY, VT, and NH. That series of tests resulted in a refined listing of plant materials and planting recommendations that were reported in several publications (Dickerson, Kelsey et al. 1997; Dickerson et al. 1997; Miller and Dickerson 1999; Dickerson 2001; Dickerson et.al. 2001, Anonymous 1992; Dickerson et al. 2002). Following is a summary of findings from the NRCS studies:

1. Native warm-season grasses have greater tolerance to stresses found on mined sites than do any other available class of plants. Valuable species include switchgrass, deertongue, coastal panicgrass (*Panicum amarum* Ell.), big bluestem (*Andropogon gerardii* Vitman), sand bluestem (*Andropogon hallii* Hack.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), indiangrass (*Sorghastrum nutans* (L.) Nash), and sand lovegrass (*Eragrostis trichodes* (Nutt.) Wood).

2. Performance differences among cultivars were noted; better performers were incorporated into seed mix recommendations (Table 1).
3. 12 to 15 pounds of pure live seed (PLS) seed mix per acre were sufficient (Table 1).
4. Mixing native WSGs and introduced CSGs tended to delay establishment of the grasses that
   provide long-term value. The WSGs dominated the site after the CSGs died from poor stress tolerance. If introduced CSG must be added for quick first year "green", tall fescue (*Lolium arundinaceum* (Schreb.) S.J.Darbyshire) was less competitive than perennial ryegrass (*Lolium perenne* L.).
5. Planting heavy rates of WSGs was self-defeating, creating extreme seedling competition and stunting overall growth.
6. Surface seeding methods were failures; effective seed incorporation was obtained by "tracking" with a dozer. Native grass drills can be used where site conditions permit, but their excellent seed placement combined with limited moisture and nutrients can result in overly heavy seedling success. As most mine sites would not permit efficient drill use, further investigation of their use was terminated.
7. Moderate amounts of macronutrients were beneficial. Limited nutrient holding capability of coarse materials and limited utilization by small seedlings can result in waste and potential loss of nitrogen and phosphorus to the water table if high rates are applied. Planting year applications of 1000 lb/ac lime with high ENV and 400 lb/ac of 10-20-20 (N, P_2O_5, K_2O) yielded results that were acceptable. On sites with very low fines content (below 8%), a second year application of fertilizer was beneficial.
8. Early planting dates (after snow melt but before May 15) were generally more effective than late dates (after June 15).
9. Effective cover was common in the second year, but could be achieved in year one with favorable weather. "Effective" meant that surface stability had been achieved.

Sand and gravel mines were not the only venues where WSGs were tested. Results at an iron and titanium mine in New York and copper mine/smelter sites in Vermont are in Dickerson et al. (2002). The copper mine/smelter sites have not demonstrated long-term success for the WSGs. Extreme acidity and heavy metal concentrations were believed to cause the decline after 4-5 years, however this was not investigated. The plantings at the iron and titanium mine in the Adirondacks remain in good condition, and help to demonstrate the utility of appropriate WSG cultivars on mine sites with a growing season lasting only about 100 days.

The success of native WSGs on stressed sites could have been expected. The grasses' attributes all pointed to effectiveness under difficult, non-native "soil" conditions in the Northeast.

Root development by the WSGs is superior to CSGs in depth and biomass. WSG seedlings partition most of the energy for growth to root production, which explains their modest above-ground size in the establishment (first) year. Preferential root growth is a hedge against dry conditions which are common on mine sites, and this is a key factor to plant longevity under stressful conditions.

Nutrient and water use efficiency are also key to WSG stress tolerance. The residual planting medium on most mine sites has poor nutrient status and low water holding capacity. Most CSGs have difficulty coping with such conditions and are prone to decline in the first dry

year or when readily available nutrients are exhausted. Mine surfaces tend to warm to greater temperatures than typical soils due to the coarse structure of the planting medium. This creates conditions unfavorable for most introduced CSG species.

Mature plant size matters. The larger stature of WSGs produces several benefits to degraded sites: erosion protection, wildlife habitat, greater microclimate adjustment, the creation of a duff layer, and more complete visual cover for aesthetic improvement. The buildup of organic matter in turn supports an array of micro and macro biota; a biological system takes shape. Plant structure, being more rigid than with the CSGs, is maintained through winters. Wildlife cover is retained and opportunity for snow trapping (improving spring moisture retention) is created. Wind erosion causes not only off-site damage and stress for neighboring properties, but also hinders the successful volunteering of local species back into the site. Native WSGs have a positive impact on the wind erosion process. The stature of WSGs through the seasons adds greatly to their value in reclamation.

Native WSGs are far more compatible with other plant types than CSGs. WSGs create protection for volunteer seedlings, conserve moisture and nutrients, and due to the bunch-grass habit of most species, inter-plant spaces are provided. Native grasslands are rich mosaics of plant species. While newly vegetated mine sites are far from "native grasslands" in any sense of the word, the building blocks are provided by native WSGs. Introduced CSGs do not have that potential.

Stand longevity matters for site remediation that lasts past reclamation bond release. The environmental benefits of vegetation that will function through the first, and subsequent, dry summers also contribute to air quality as the site performs its role in sequestering carbon dioxide, reflecting radiation, filtering pollutants, trapping dust, and cooling the air stream.

Methods

The Wildlife Information Center (WIC) developed a revegetation concept that utilizes WSGs to revegetate the contaminated slopes of the refuge. Viacom International, the responsible party under the Superfund law, assigned the task of turning this concept into a remedial action plan to its environmental engineering firm, Frank and West Environmental Engineers (F&W). F&W personnel worked with Kunkle and Dickerson in a process that resulted in a design to create 56 one-acre test plots on WIC land in 2003 (Frank 2003). The plan was approved by EPA and implemented in May-July 2003.

Eight WSG species were selected for the test plot applications (Table 2). Dickerson advised the F&W engineers regarding soil amendments and application rates to be used on the test plots. F&W devised the planting methods. The final product was a negotiated plan that needed to satisfy the demands of the local conservation district, U.S. EPA, PA DEP, U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, and other agencies involved with oversight of the Palmerton Superfund site.

Frank and West developed two application methods. An aerospreader truck, developed by Horsehead Industries, blew the planting mixture onto the land adjacent to an abandoned rail bed. Areas more than 100 feet from the rail bed and with a slope less than 25% were planted with a rubber-tracked Caterpillar Challenger tractor and manure spreader combination, which distributed the mix from the rear of the spreader. Limestone, commercial fertilizer, and compost were the soil amendments added to the plots along with grass seed. The test plots included various mixtures, but the primary variable was the compost. Application rates of seed and soil amendments are shown in Tables 2 and 3.

The planting season was delayed, beginning in mid-May, but favorable weather with adequate rainfall prevailed and the seeding continued into July in 2003. The main WSG species expected to dominate the site after establishment are big bluestem, indiangrass, switchgrass, little bluestem, and eastern gamagrass (*Tripsacum dactyloides* (L.) L.) Since the site is severely stressed and met the conditions outlined in Table 1, we decided to add the species marked "b" and "d" to help us with early establishment of cover and erosion control. These bridge species, including coastal panicgrass, sand lovegrass, and sand bluestem, were expected to emerge early in the process as dominant species, providing conditions in which the long-term species would thrive. The bridge species have diminished in abundance and will die out as the long-term species increase.

The plan included use of heavier application rates of the grass seed than recommended in the mine reclamation research. Because of the extreme physical conditions of the site, tracking of much of the area with a bulldozer is impossible. Those areas planted with the Challenger tractor could be tracked, but large numbers of rocks and boulders made travel difficult and expensive (constant repairs are needed for the tractors and spreaders), so F&W did not track the plantings. This reduced seed-soil contact, and therefore reduced the potential for germination, leading to the decision for higher rates of application. Even though WSG seed is usually more expensive than CSG seed, it is among the least expensive parts of the reseeding process at this site.

More lime per acre was used than indicated in the mine research. This was the result of EPA's Record of Decision, requiring that the metals be fixed in the soil and not allowed to be dissolved into runoff or groundwater. The metals involved are poorly soluble at neutral pH, but become more soluble as pH lowers. The pH of the soil on the site was an average of 4.5. Four tons/acre of lime was added to increase pH to about 6.5 to fix metals in the soil (Frank 2003).

To meet the erosion and sedimentation control requirement of the Carbon County (PA) Conservation District, applying PA DEP rules, we were required to add CSGs (Table 2) to the planting mixture on the step banks along the rail bed where the mix was applied with the aerospreader truck. As with the WSG bridge species, these CSG species have declined in abundance as the WSG species increase over time.

Results

Excellent growing conditions prevailed during 2003, allowing planting to continue through mid July. Coastal panic grass and sand lovegrass were the dominant species seen in the establishment year (as expected), and many plants reached three to four feet in height, flowered, and set seed in 2003 (Kunkle 2003). This was surprising given the stressful conditions at the site. A cool-season native, Canada wild rye (*Elymus canadensis* L.) was also prominent where planted.

Again in 2004 the weather was wetter than average, leading to excellent growth. By the end of the second growing season, the grasses had already exceeded the proposed performance standard of 70% live grass and rocks greater than two inches, as measured by point counts at randomly selected locations in most test plots (West 2004a). In addition, total cover data showed a strong increase in 2004 compared with 2003 (Table 4). Not only were the grasses increasing in abundance within the plots, but also were spreading, primarily downhill, from the test plots, filling in the buffer zones and rendering the test plot boundaries indiscernible.

Mushroom compost showed the best results in promoting grass germination, establishment, and growth in the first two years of the plots. Duck and turkey manure proved effective, but are unavailable at reasonable prices in large quantities. Lehigh County leaf compost is readily available in large quantities at a reasonable cost and also performed well. Biosolids and straw mulch performed poorly in the establishment year, but improved in the second growing season. No-mulch plots lagged in seed establishment and total cover. Based on these results and availability, it was decided that mushroom compost would be the preferred compost, with Lehigh County leaf compost used as a back up when full scale planting operations occurred.

Tests regarding metal uptake were performed by BBL, Inc. for Viacom International. BBL also performed a risk assessment analysis based on the metal uptake data. While the data and risk analysis are not yet publicly-available, the uptake studies showed relatively low levels of uptake compared to pioneering tree species, and there was no significant risk found for either wildlife or people from the levels of metals being taken into the grasses. (EPA, personal communication)

The addition of nutrients to the site, plus improved microclimate due to grass structure, created conditions in which pioneering natives and aggressive invasive species would be able to gain a foothold. In 2004, there was a noticeable increase in colonization of the test plot areas by other plant species. Gray birch (*Betula populifolia* Marsh.) and, to a lesser extent, aspens (*Populus sp.*) began colonizing the site in small numbers. Other colonizers included desirable herbaceous plants that increase the diversity of the developing grassland ecosystem, but others were invasive species that posed a threat to the restoration project (Kunkle 2004).

The main invader was butterfly bush (*Buddleja davidii* Franch.), with a lesser number of tree of heaven (*Ailanthus altissima* (Mill.) Swingle) also appearing, apparently from nearby seed sources along the Lehigh River and the abandoned rail beds. In September 2004, we removed approximately 7,000 Buddleja and 100 Ailanthus plants by pulling them out. This was effective, since the plants were still small enough to remove by hand, and the roots could be removed fairly effectively. In the test plot areas where this work occurred, the *Buddleja* have not returned to the extent they had earlier, although the *Ailanthus* are invading in increasing numbers. In 2006, we are removing the invasives using glyphosate herbicide (50% strength) applied directly to the leaves and/or bark of the target plant with a sponge paintbrush. This is having the desired effect.

In 2003, volunteers from the Wildlife Center carried the seed mix only (no amendments) to a steep, rocky area of the refuge above the test plots and broadcast it by hand. This resulted in a promising amount of germination. As a result, Viacom International used a crop duster airplane to apply seed (WSGs) and fertilizer to 84 acres of steep slope in 2004 (West 2004b). Germination was good, with as many as 20 or more seedlings per square foot noted in some locations. In August of 2004, lime was applied at rates of 1, 2, and 4 tons per acre to three test strips. These strips outperformed the surrounding areas very quickly, thus lime was used in future aerial applications (Kunkle, unpublished data).

During the third growing season in 2005, a severe drought ensued. The WSGs in the original test plots performed as expected, having had two good growing seasons to establish deep root systems as reported by West in 2004. While the WSGs did not grow as tall in 2005, they seeded profusely and no mortality was seen. The most notable development in 2005 was the increase in number of the long-term species that were producing seeds, and the

decrease in dominance of the bridge species. Eastern gamagrass, indiangrass, switchgrass, and big bluestem all became prominent species in the third year, while the prominence of sand lovegrass and coastal panicgrass decreased as expected. The grassland was becoming more balanced in terms of species composition of WSGs, and Canada wild rye continued to perform well (Kunkle 2005).

In the aerial application area, the drought took a heavy toll. Much of this area is heavily covered with rocks, with the seedlings sprouting from gaps between the rocks. Areas with less rock had responded well to the aerial seeding. By the end of 2004, many 6-12 inch seedlings were seen throughout the steep-slope area. Spring greening began before the drought hit, showing that the winter kill had been minimal. However, the drought killed as many as 50% of the seedlings in most areas, indicating that the plants had not developed deep enough roots in the establishment year in this stressed environment to survive the drought. Significantly, the strips with the lime tests did not suffer a great deal of seedling death, reinforcing the importance of adding lime to the aerial application (Kunkle 2005).

Discussion

There are many signs that it is not only a plant community that is being established, but also that a functioning ecosystem is developing. Macroscopic soil organisms are increasing in abundance, and though no microscopic analysis has been performed, a decomposer system has apparently been developing. Above ground, the diversity of wildlife on the site is increasing dramatically. Insect populations have developed creating a prey base for insectivorous birds such as Eastern Bluebirds (*Sialia sialis*) and Northern Mockingbirds (*Mimus polyglottos*). Tree Swallows (*Tachycineta bicolor*) abound and Eastern Bluebirds are common, using nest boxes installed for these species. American Kestrels (*Falco sparverius*) are nesting in boxes provided by the Wildlife Center, and red foxes (*Vulpes vulpes*) denned on the refuge in 2006. The presence of breeding kestrels and foxes as well as ever-present Red-tailed Hawks indicates the building of a stable small mammal (mice, voles, chipmunks) population.

Seed eating birds such as sparrows, doves, and finches, have taken advantage of the grasses as a source of seed and cover. Groundhogs (*Marmota monax*), wild turkeys (*Meleagris gallopavo*), white-tailed deer (*Odocoileus virginianus*), timber rattlesnakes (*Crotalus horridus*), black rat snakes (*Elaphe obsoleta*), and coyotes (*Canis latrans*) have been sighted in the test plots. These animals are an indication of the habitat being created by the grasses and other species established on the refuge.

Beginning in early spring 2006, the Wildlife Center and CBS Operations (formerly Viacom International Inc.) began full-scale vegetation of the remaining areas of the Lehigh Gap Refuge and additional areas of private lands in the Palmerton Superfund area. Aerial application took place in late March and early April to several hundred acres, including the areas applied in 2004. Land based application commenced as soon as the aerial work was completed. By mid-June, most of the Wildlife Information Center lands were seeded (Frank 2006).

The mix used in 2006 for the aerial application included WSGs, limestone (1 ton/acre) and commercial fertilizer (N 160 lb/ac, P 130 lb/ac, K 290 lb/ac). The land based application used compost (mushroom or Lehigh County), lime, and fertilizer at the rates shown in Table 3. Sand bluestem was removed from the WSG seed mix because of poor performance, and Canada wild rye (cool-season annual) was added (15 lb PLS/ac) because of its excellent

performance in the original plots. At the request of the oversight agencies, three additional native WSGs were added to the mix at 2 lb PLS/ac: deertongue, purple top (*Tridens flavus* (L.) Hitch.), and broomsedge (*Andropogon virginicus* L.) (Frank 2006).

In order to encourage the development of a more diverse grassland ecosystem, 11 species of native, herbaceous flowering plants (Table 5) were added to the original test plot area by hand seeding in June 2006. If successful, we will add these species and others in coming years.

In the long term, succession and invasive species will erode the quality of the grassland habitat without proper management. Our intention is to manage the re-vegetated grassland areas of the refuge as grassland/savanna with the addition of scrub oaks and other oak species to the habitat. The plan also calls for continued enhancement of the habitat with other flowering species and the addition of more nest boxes.

We recognize the difficulty of managing this habitat in the long-term, and expect to use a management strategy that includes controlled burns along with physical removal and spot treatment with herbicides to eliminate the invasives and most woody species to maintain the grasslands. The fire tolerant oaks will also be benefited by fire.

In order to establish baseline ecological data for the refuge, the Wildlife Center has engaged Natural Lands Trust of Media, PA to conduct an ecological assessment of the Lehigh Gap Wildlife Refuge. The final report of the ecological assessment (January 2007) will outline an adaptive resource management plan for grassland management and enhancements on the lower slopes of the refuge, including monitoring protocols (Steckel 2006). Finally, the Superfund law (CERCLA) requires 5-year reviews of the revegetation remediation. These reviews include re-evaluation of the effectiveness of the remedy, and will provide valuable information that will inform future management.

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Table 1. The basic warm-season grass mixture that has been successful on critical areas in the Northeast. The seeding rate is typically close to 12 pure live seed (PLS) pounds per acre. Note: new eastern selections are pending for indiangrass and little bluestem (USDA-NRCS).

Species Common Name	Cultivar(s)	Origin	PLS lb/ac
Switchgrass(a)	Shelter or	WV	2.0
	Pathfinder	NE	2.0
Coastal panicgrass (b)	Atlantic	NJ	2.0
Deertongue (c)	Tioga	PA-NY	1.0
Big bluestem	Niagara	NY	3.0
Little bluestem(a)	Aldous or	KS	2.0
	Camper	NE	2.0
Sand bluestem (d)	Goldstrike	NE	2.0
Sand lovegrass (a)(d)	Bend or	KS	2.0
	NE-27	NE	2.0
Indiangrass (e)	Rumsey	IL	2.0

(a) Use one cultivar, not both. (b) Add where fines are 15% or lower. (c) Add if wet spots are within area, otherwise omit. (d) Add where fines are below 10 percent. (e) Add where fines are above 15 percent.

Table 2. Grasses and application rates (sci. names have been presented in text except below Canada wild rye)

Grasses	Application Rates
Warm-season Grasses (all test plots)	lb PLS/ac
Big Bluestem (*Andropogon gerardii*, Niagara)	6
Sand Bluestem (*Andropogon hallii*, Goldstrike)	2
Little Bluestem (*Schizachyrium scoparium,* Aldous)	4
Switchgrass (*Panicum virgatum*, Shelter and Trailblazer)	6
Sand Lovegrass (*Erogrostis trichodes*, Bend)	4
Indian-grass (*Sorgastrum nutans*, Osage)	4
Coastal Panicgrass (*Panicum amarum*, Atlantic)	4
Eastern Gamagrass (*Tripsacum dactyloides*, Pete)	4
Annual Cool-season Grasses (selected test plots)	
Canada Wild Rye (*Elymus canadensis*)	5
Annual Rye (*Lolium multiflorum* L.)	5
Spring Oats (*Avena sativa* L.)	5
Perennial Cool-season Grasses (selected test plots)	
Hard Fescue (*Festuca sp.*)	5
Sheep Fescue (*Festuca ovina* L.)	5
Hairgrass (*Deschampsia flexuasa* (L.) Trin.)	5

Table 3. Soil amendments used in the revegetation work.

Amendments	Application Rates
Commercial Fertilizer	
Nitrogen	160 lb/ac
Phosphorus	80 lb/ac
Potassium	130 lb/ac
Limestone	4 tons/ac
Organic amendment (one of the following)	
Mushroom compost	10 tons/ac
Lehigh County municipal compost	10 tons/ac
Duck manure	10 tons/ac
Turkey manure	10 tons/ac
Pelletized sewage sludge	10 tons/ac
Straw mulch	1 bale/1000ft^2

Table 4. Total cover analysis data for WIC test plots in 2003, 2004.

Total Cover Year/Properties	Mushroom Compost	Lehigh Co Compost	Duck Manure	Turkey Manure	Biosolids	Straw Mulch	No Mulch
2003 Live Grass	63%	47%	36%	53%	29%	35%	18%
2003 Live Grass, Rock>2"	74%	59%	49%	79%	43%	49%	44%
2004 Live Grass	81%	64%	65%	78%	64%	64%	39%
2004 Live Grass, Rock>2"	88%	78%	81%	92%	77%	77%	64%

Table 5. Enhancement species added to test plot areas in 2006.

Common Name	Scientific name
Partridge Pea	*Chamaecrista fasciculata* (Michx.)Greene
Wild Senna	*Senna hebecarpa* (Fern.) Erwin& Barneby
Wild Lupine	*Lupinus perennis* L.
Round-head Lespedeza	*Lespedeza capitata* Michx.
Butterfly Milkweed	*Asclepias tuberosa*L.
Common Milkweed	*Asclepias syriaca* L.
Ox eye Sunflower	*Heliopsis helianthoides* (L.) Sweet
Black-eyed Susan	*Rudbeckia hirta* L.
Brown-eyed Susan	*Rudbeckia triloba* L.
Smooth Blue Aster	*Aster laevis* L. = *Symphotrichum laevis*
Dense Blazing Star	*Liatris spicata* (L.) Willd.

Native Grasslands and Meadows in Pennsylvania: Their History and Current Condition

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Studies of fossil remains, including bones, pollen, spores and charcoal, have painted a provocative picture of the evolution of grasslands over the past several million years in North America. However, comparatively little scientific inquiry on native grasslands has focused on the northeastern United States, where forests and wetlands attract far more attention. In this study, eyewitness accounts and vascular plant species lists were compiled for more than 250 historical and present-day native grassland and meadow sites within the present-day borders of Pennsylvania. Grasslands are estimated to have covered 600 to 620 km^2 around the time of European contact, just over 0.5% of the state's total land area (for comparison, estimated present-day wetland cover is 980 km^2 or 0.8%). Today, remnants of pre-European-settlement grasslands sum to less than 2.5 km^2, a 99.6% decline, which continues and is even accelerating at many sites. Other persistent, unplanted grasslands of more recent origin that are dominated by native species raise the total to around 8.5 km^2, less than 2% of the historical extent and 0.01% of the state's land area. In strong contrast, more than 25% of the plants on the list of endangered, threatened and other species of special concern in Pennsylvania typically inhabit persistent (not short-lived, early successional) grasslands and meadows. Detrended correspondence analysis of herbarium records clarified patterns in the composition of grassland-endemic plant species at 173 of the historical sites, in relation to physiography, bedrock type and other elements of geographical variation. An expanded community classification scheme is proposed for native, upland grasslands and meadows in the state. Results of this study are useful (1) as input for a gap analysis establishing natural area protection priorities, (2) to define models of species composition for management and restoration of remnant grasslands, (3) to create templates for the creation of new native grasslands that will favor success in establishment and enhancement of wildlife habitat under particular sets of soil and microclimatic conditions, and (4) to identify the best sources for local genotypes of species used in restoration and grassland creation.

Key words: Endangered species, management, northeastern grasslands, remnant grasslands,

Wetland Reserve Program Levee Planted to Native Warm-Season Grass

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Native warm-season grass buffers have come into their own in recent years, due to the USDA Buffer Initiative and increased awareness of wildlife. Additionally, native warm-season grasses have become more prominent in use due to factors including mandates to utilize native species, problems with invasives, lower long-term costs of natives, and better adaptability to local conditions. As native warm-season grasses have become more popular and their use increased, a wider variety of applications have come to the fore, with multiple benefits both primary and secondary. This poster looks at the recent success and utilization of native warm-season grass borders in the Lower Mississippi Valley, and the direct application on a Wetland Reserve Program (WRP) levee.

A moist soil unit on a WRP tract is parallel to a public road. The road utilization diminishes the habitat value of the unit. When considering some form of screening, it was determined that the most beneficial barrier would be one composed of native warm-season grasses. This would create a barrier of natives (aWRP requirement) while maximizing wildlife utilization. The following mix and planting rates were utilized.

Plant material	Recommended planting rate (lbs pure live seed/ac)	Seed for 5 acres of levee (lbs)
'Alamo' Switchgrass (*Panicum virgatum* L.)	6	30
'Lometa' Indiangrass (*Sorghastrum nutans* L.)	1	5
'Kaw' Big Bluestem (*Andropogon gerardii* Vitman)	1	5

Levees had been constructed the previous fall, and planted to wheat as a cover. Seed was no-till drilled into wheat stubble using a Truax drill with a fluffy seedbox. This provided the proper seedbed and utilized the proper equipment. The cultivars selected are all adapted to the region. Management will now be the main component in assuring the proper stand and long-term health and vigor of the native warm-season grass buffer.

Key words: Big bluestem, grass buffers, indiangrass, switchgrass

Rehabilitating Sandy Soil Military Lands with Native Plants

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Planting native grasses on military facilities provides a low-maintenance, long-term vegetative cover to retard soil erosion, but requires proper species selection and seeding methods if they are to establish while the land is being used for training. At Fort Drum, New York, the soils are sandy and the land can be severely disturbed. The combination of the need for rapid establishment and sandy soils makes using native plants a challenge. We found that the use of liquid cow manure and no-till methods works for cost-effective seeding. We also found that seeding mixtures of native and introduced plants can establish vegetation more rapidly than native plants alone in these poor soil conditions, allowing the military to reuse the sites relatively quickly. These ecological-bridge seeded areas eventually transition into a native-plant vegetative cover that has been shown to have long-term resiliency.

We tested the ecological-bridge concept by using seed mixtures consisting of a one-year nurse crop, a group of introduced fine fescues [hard and sheeps types; *Festuca trachyphylla* (Hack.) Krajina; and *F. ovina* L., respectively], and the native species switchgrass (*Panicum virgatum* L.). For the nurse crop we used weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees], which is susceptible to winter kill and shows promise as a nurse crop for slow-growing native species and for short-term rehabilitation of intensively used sites. We applied liquid cow manure at varying rates (20 to 40 tons/acre) to modify surface soil temperature and retain moisture. The seed mixture was sown with a no-till seeder into the manure cover. The weeping lovegrass provided greater than 80% cover in the first season. After the initial season, switchgrass and the fine fescues grew through the dead weeping lovegrass and began to dominate the site. This mixture proved successful in producing native plant stands and has been used by Fort Drum to rehabilitate training and bivouac areas for the last five years.

At the completion of one ecological-bridge study, the area was used as a defilade position in which the soil was severely disturbed by the digging of a soil depression for tank concealment. When this site was later leveled and the hole filled in, the switchgrass re-established on its own with no invasive weeds despite the severe soil damage. Elsewhere at Fort Drum, berms with steep slopes were constructed for force protection in two areas: one area had been seeded with the ecological-bridge mixture about four years earlier and the second adjacent area contained naturalized species and had not been recently seeded. On the berms in the naturalized area, parts of the berm were dominated with the invasive weed spotted knapweed (*Centaurea biebersteinii* DC). In the berm area previously seeded with the ecological-bridge seed mixture, the switchgrass regrew on its own and was able to successfully out-compete the knapweed.

Key words: Ecological bridge, establishment, fine fescue, weeping lovegrass

Experimental Restoration of Wiregrass Communities

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Wiregrass (*Aristida stricta* Michaux) is a perennial, native bunch grass of the Atlantic Coastal Plain and an integral component of the longleaf pine (*Pinus palustris*) ecosystem. It depends on growing-season fires to enter a reproductive state. However, use of prescribed fires is declining due to smoke management and liability concerns. Herbicides have been used to stimulate regeneration of wiregrass, but their effect on other native herbaceous species is relatively unknown. We are comparing the effect of two herbicides, hexazinone and imazapyr, on the regeneration of wiregrass and other native groundcover vegetation, with and without fire. Our study sites are on disturbed areas within the former longleaf pine-wiregrass range, and consist of 18 plots in each of three sites. We are recording percentage horizontal cover, height of vertical cover, and percentage of vertical structure of plant species within plots. Frequency of occurrence of plant species is also measured using a point-count method to estimate diversity. Vegetative sampling will continue through spring, summer, and fall 2006. First year (2005) data reflect a change in horizontal grass, forb, and woody cover ($P = 0.0416$, $P = 0.0036$, $P= 0.0093$, respectively) among treatments. Vertical structure was significantly different among treatments up to 3.3 ft ($P = 0.0257$). Significant differences in diversity were detected between imazapyr and hexazinone application plots with average means of 2.4 and 1.8, respectively (Shannon-Wiener index). Our first year results suggest that imazapyr, with and without fire, is more effective at suppressing hardwood species that inhibit the growth of wiregrass and other native groundcover vegetation.

Key words: Hexazinone, imazapyr, longleaf pine (*Pinus palustris*), wiregrass (*Aristida stricta* Michaux).

Virginia Wildrye Evaluations in Riparian Zones

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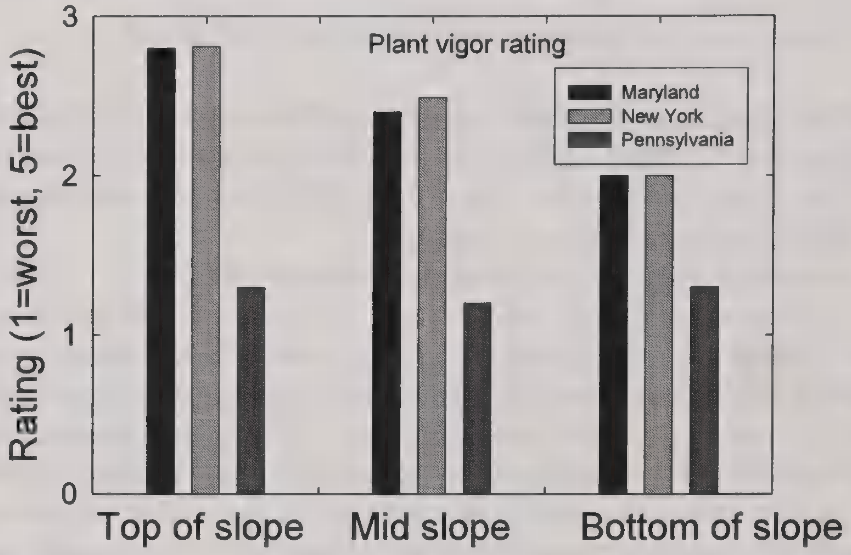
www.ars.usda.gov/main/site_main.htm?modecode=19020000

Virginia wildrye (*Elymus virginicus* L.), a perennial cool-season grass native to the northeastern USA, grows along streams, forest margins, and in other wet areas. In this multilocation study, we compared four accessions of Virginia wildrye with a commercial ecotype (Pennsylvania Ecotype, Ernst Conservation Seeds) and a cultivar (Omaha, Stock Seed Co.) on wet soils at four locations. Accession 1 was collected in Montgomery county MD; Accession 2 in Chemung county NY; and Accession 3 in Cheshire county NH. Plants of Accession 4 were of unknown provenance but survived a severe drought on sandy soil at Beltsville MD in 2002. The four accessions, commercial ecotype, and cultivar were transplanted into single-row plots of 17 plants per plot. Each plot contained 15 experimental plants and a border plant of wildrye at each end. Plants were spaced 1-ft apart with 1 ft between rows. Rows were oriented parallel to the slope so that each accession was evaluated at the top, mid, and bottom slope positions. Evaluation sites were near Wye, MD; Klingerstown, PA; Mansfield, PA; and Big Flats, NY. Experimental plants were rated for survival, plant vigor, and plant height in September 2004 and in April or May of 2005 and 2006. Differential vigor and survival was noted among accessions and among landscape positions within each location (Fig. 1). The commercial ecotype and cultivar Omaha survived well at all locations, as did Accession 3. Accession 4, collected from a field experiment in Beltsville, MD, had very low survival at each location. Plant survival, vigor, and plant height were greatest at the top slope landscape position compared with the midslope and the bottom of the slope. Evaluations will be completed in 2007.

Key words: Cool-season grass, landscape position, wet soils

Fig. 1. Plant vigor ratings at three landscape positions averaged for three sites.



Native Warm-Season Grasses for Riparian Zones

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In a previous pot experiment we identified several warm-season grasses with the ability to extend their roots into saturated soils, making them potential candidates for use in riparian zones. In this experiment, we verified results from the pot study by evaluating a range of cultivars under field conditions. Four field locations in New York, Pennsylvania, and Maryland were selected for the study. Each location was subjected to high soil water tables or periodic flooding during various times during the year. Nine warm-season grass cultivars from five species including big bluestem (BB), *Andropogon gerardii* Vitman., switchgrass (SG), *Panicum virgatum* L., indiangrass (IG), *Sorghastrum nutans* L., prairie cordgrass (PC), *Spartina pectinata* L., and eastern gamagrass (EG), *Tripsacum dactyloides* L. were included in the study. Individual plants were started in the greenhouse then transplanted to the field in May 2004. Each plot consisted of three rows planted on 1-ft centers. There were four replications. The rows ran perpendicular to the stream bed or other water source with the two outside rows and the plant on each end of the center row serving as borders. Plants in the center row of each plot were evaluated for survival and vegetative vigor in the spring of 2005 and 2006, and for yield in the fall of 2005. Prairie cordgrass had excellent survival and growth at all locations (Table 1) but produced an open canopy that reduced its yield compared to other high ranking cultivars. It was the only cultivar with rhizomatous growth and tended to spread outside of its planted rows. Eastern gamagrass had excellent survival and yield at all but one site, where extreme flooding almost eliminated it from the stand. 'Hightide' switchgrass provided the best combination of survival and yield across locations. The pot study appeared most useful for eliminating poor performing cultivars but was only marginally effective at identifying the best cultivars.

Key words: Cultivar evaluation, native grasses, wet soils,

Table 1. Relative survival, vigor (plant height), and yield for nine warm-season grass cultivars grown under saturated soil moisture conditions at four locations in NY, PA and MD.

Cultivar	Survival (2006)	Vigor (2006)	Yield (2005)	Overall
	Relative ranking (1=best, 9=worst)			
Red River PC	1	1	4	2.0
Hightide SG	2	3	1	2.0
NY tetraploid EG	4	2	2	3.0
Shelter SG	3	4	3	3.3
Osage IG	7	5	7	6.3
Niagara BB	5.5	6	8	6.5
Suther BB	5.5	8.5	6	6.7
Suther IG	8	8.5	5	7.2
Bonilla BB	9	7	9	8.3

Roadside Management

Cold Shoulder to Warm-Seasons: Vermont Agency of Transportation

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Warm-season grasses have been successfully planted in Vermont by the U.S. Soil Conservation Service since 1985, primarily for sand and gravel pit reclamation. Since that time the Vermont Agency of Transportation (VTrans) has collaborated with the USDA Natural Resource Conservation Service to promote the use of these grasses in highway rights-of-way. Although VTrans won't be turning their roadsides into tall grass prairies any time soon, warm-season grasses have been tested in field trails and incorporated into some critical area plantings and for wildlife habitat enhancement. Because of the challenges of establishing warm-season grasses in the Northeast, highway departments have given the cold shoulder to their uses. VTrans recognized the value of these very important grasses and despite the lack of any large plantings continues to research and establish demonstration plots to help educate land managers about the many benefits of these plants.

Key words: Benefits, challenges, collaboration, promotion

Are Native Grasses a Viable Alternative to Crownvetch for Roadside Slopes?

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Crownvetch (*Coronilla varia* L.) is an exotic legume that has been used to successfully reclaim highway construction cut- and fill-slopes in Pennsylvania for 50 years. Crownvetch is increasingly described as an invasive species, primarily by non-government organizations, but also by some state agencies, including the Pennsylvania Department of Conservation and Natural Resources. Crownvetch use is discouraged but not regulated by the Federal Highway Administration, and the US Department of Agriculture-Natural Resource Conservation Service (which released the varieties 'Chemung' and 'Emerald') now describes crownvetch as 'useful but overused'. Selective removal of herbaceous and woody dicot weeds is more difficult in crownvetch than in a grass groundcover. Additionally, anecdotal accounts and observations suggest that crownvetch is effective at providing soil cover in poor conditions, but due to its viny habit and coarse root structure, it is less effective than grasses in preventing soil erosion from surface flow and preventing slides and slope failure.

After research trials and operational-scale demonstrations using native grasses such as big bluestem (*Andropogon gerardii* Vitman), deertongue (*Dicanthelium clandestinum* (L.) Gould), Canada wildrye (*Elymus canadensis* L.), switchgrass (*Panicum virgatum* L.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash) and Indiangrass (*Sorghastrum nutans* (L.) Nash), we offer the following observations:

- The native grasses establish more slowly than crownvetch on poor sites, and a seed mix requires intermediate-term components, in addition to single-season cover crops such as annual ryegrass (*Lolium perenne* ssp. *multiflorum* (Lam.) Husnot).
- Roadside seedings that are intended to be crownvetch-free will require use of sanitation protocols to prevent crownvetch introduction by way of contaminated hydraulic seeders.
- Incorporating native forbs with native grasses to enhance the habitat or mitigation value of a seeding complicates early-stand weed management, particularly if crownvetch is one of the weeds.
- A successful native grass-based seed mix for highway construction will be successional, and the final results will be difficult to demonstrate in a timeframe conducive to convincing highway engineers to change plant material specifications.

Key words: Highway construction, invasive species, roadside seeding

A Non-Traditional Application for American Beachgrass, *Ammophila breviligulata*

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Ammophilia breviligulata Fern., American beachgrass, is a native of the mid-Atlantic coastal region from Maine to North Carolina and the Great Lakes and is the predominant plant species utilized for initial stabilization of frontal sand dunes. American beachgrass is a cool-season perennial, rhizomatous grass that will grow to a 2- to 3-ft height and tolerate annual over-topping accumulations of sand up to 1 ft. This grass is a poor seed producer and must be propagated vegetatively. It will grow on sandy or other coarse textured soils on inland sites with or without high salinity, provided supplemental fertilizers are used. Culms of 'Cape' American beachgrass, a cultivar developed at the USDA-NRCS Cape May Plant Materials Center, were hand planted on a steep, extremely sandy, highly erosive highway construction site near Wardensville, West Virginia in March 2003. Objectives were: to control erosion and stabilize the site using a North American plant well adapted to the site's sandy Udorthent soil and to establish microclimate conditions conducive to succession by locally adapted plant species. Culms were planted on 2-ft centers and two culms were placed in each dibble hole along with 15 grams of 16-8-12 analysis slow release fertilizer tablets. Efficacy of the planting is monitored via visual observations conducted annually. 'Cape' American beachgrass has clearly achieved the erosion control and site stabilization objective, and is providing a suitable microclimate for natural re-establishment of endemic species. The successful utilization of American beachgrass at this site demonstrates the potential for use of native plants in many non-native (man made) applications and settings.

Key words: 'Cape' American beachgrass, construction site stabilization, erosion control

Evaluation of Cool-season Grasses for Weed Suppression in Landscape and Roadside Settings

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Abstract

Nineteen cool-season grass cultivars were selected for further field evaluation after thorough literature review, based upon their potential to overwinter well in the Northeast and to tolerate stressful roadside conditions. We were particularly interested in their winter hardiness, and ability to rapidly establish a dense stand and suppress annual and perennial weeds under minimal maintenance, simulating roadside management. Grasses were seeded on September 10, 2005 at approximately 4lbs/1000 ft^2 on a well-drained Hudson silt loam soil in Ithaca NY, at the Bluegrass Lane Turf and Landscape Research Center. Plots were evaluated in April 2006 for winter hardiness and survival, and later in May, June and July 2006 for their ability to produce cover or above-ground biomass, and also to suppress the establishment of weeds. Plots received no fertilization and no irrigation after seeding, and minimal monthly mowing with a large commercial rotary mower. Grasses which performed well in terms of weed suppression and biomass production included crested wheatgrass, creeping meadowgrass, no-mow fescue, 'Rebel' 'Exceda' tall fescue, and Russian winter rye. 'Columbra' and 'Intrigue' chewings fescue and 'Prelude' perennial ryegrass were exceptionally good performers. These cultivars generally produced greater than 90% stands of cover with minimal weed infestation by July 10, 2006. Grasses which performed poorly as evaluated by formation of less than 60% stands and supported large weed infestations included 'Reliant II' fine fescue and Arizona fescue. Grasses will be further evaluated for their ability to withstand environmental stress and perform under low maintenance conditions both in Ithaca and Riverhead NY locations and in selected roadside settings.

Key words: Cool-season grasses, low maintenance, roadside, weed suppressive

Introduction

Many northeastern states have Departments of Transportation that are greatly interested in improving the quality of roadside turf in medians and near guiderails. The selection of a turf mixture for seeding large areas next to the roadside involves several key criteria for enhanced performance. First, the groundcover must require limited mowing maintenance to reduce labor costs. Secondly, it must require limited irrigation or rainfall and tolerate poor soils, pH extremes and high salinity upon occasion. Thirdly, a successful roadside planting must suppress weed infestation and reduce spread of invasive weeds in these settings, while not attracting deer or other dangerous mammals to the roadside. Lastly, it should provide an appearance that is aesthetically pleasing over time, with limited reseeding requirements. Given these criteria, it is a challenging task to select one groundcover that meets all of these requirements. However, recent research is now underway to select for enhanced salt tolerance and stress resistance in low maintenance grass breeding programs at the University of Rhode Island and at Rutgers University. In

addition, field screening of roadside grasses are underway at the University of Rhode Island, Pennsylvania State University and Cornell University, among likely other programs (Weston et. al. 2006; Eom et.al. 2005).

In attempting to surmise which grasses or mixtures of grasses might later be suitable for roadside establishment in New York State with respect to the above-mentioned criteria, a literature review revealed that certain fine leaf and other fescues are known to be exceptionally weed suppressive over time from previous field evaluations (Bertin and Weston 2003; Weston and Bertin 2004). In some cases, weed suppression provided by established grass stands has been attributed to competition for resources and also to allelopathic plant properties (Weston 1996; Weston and Duke 2003; Weston 2005). In addition, it has been suggested that other native species may be well-adapted to NY State growing conditions and also able to prevent erosion and weed infestation when well-established (Eom et. al. 2005; Eom et. al. 2006). However, not a great deal of work has been conducted on this subject using replicated field trials and controlled seeding conditions for evaluation. Therefore, we evaluated a selection of twenty cool-season native and non-native grasses in two locations, Ithaca and Riverhead NY. For purposes of this manuscript, we will present results from only the Ithaca location at this time.

Materials and Methods

Nineteen cool-season grass cultivars were selected for further field evaluation based upon their potential to overwinter well in the Northeast and to tolerate stressful roadside conditions, after a thorough literature review (Table 1). We were particularly interested in the grasses' winter hardiness, their ability to rapidly establish a dense stand after seeding, and also to suppress annual and perennial weeds under minimal maintenance, simulating roadside management conditions. Grasses were seeded on September 10, 2005 at 4 lbs/1000 ft^2 on a well-drained Hudson silt loam soil in Ithaca NY, at the Bluegrass Lane Turf and Landscape Research Center. Plots were seeded by hand after preparation by tillage and cultivation, and after seeding plots were rolled to increase seed soil contact to enhance germination. Plots were not irrigated or fertilized following seeding. Plots were evaluated in April 2006 for winter survival, and later in May, June and July 2006 for their ability to produce cover or above-ground biomass, and also to suppress the establishment of weeds. Plots received minimal monthly mowing with a large commercial rotary mower to simulate roadside typical roadside management conditions.

Discussion

Initial evaluation of grass plots indicated that several had not successfully established or overwintered when evaluated in early April. Limited to no growth was present in plots seeded to redtop, 'Zenith' zoysiagrass, 'Sandpiper' chewings fescue, 'Reliant II' hard fescue and Arizona fescue. Several of these grasses including 'Sandpiper' and 'Reliant II' fine fescue as well as redtop and zoysiagrass were generally well established with significant ground cover by July, indicating a longer period for adequate biomass generation was observed in the Ithaca environment. However, Arizona fescue currently has limited establishment in this field site. Since all seed purchased was fresh and growing conditions including rainfall amounts, snow cover and warm spring temperatures were optimal, it may be that this native fescue is not well-adapted to this region or is particularly difficult to germinate and establish.

In comparison, several grasses were well-established by early April, particularly 'Prelude' perennial ryegrass, thereby preventing early season weed infestation to occur in these plots, due to adequate cover and competition for resources. Grass establishment, biomass production and percent overall cover continued to increase through July, with certain tall fescues and fine fescues performing well, including 'Rebel Exceda' and 'Tar Heel II' tall fescue, as well as 'No-mow', 'Intrigue' and 'Columbra' fine fescue. Good performers also included crested wheatgrass and creeping meadowgrass, along with Russian wild rye. Weed suppression tended to be strongly and positively correlated with increased cover provided by the cool-season grasses. Although weed growth increased over time, certain covers were still exceptionally weed suppressive with limited to no infestation of annual or perennial weeds by July 2006. In addition, certain cool-season grasses exhibited strong aesthetic appeal. Those that provided good dark green color and texture, along with dense cover included perennial ryegrass 'Prelude' and several fine fescues, along with Russian wild rye. Wheatgrasses and meadowgrass appeared to be somewhat chlorotic in May and June and appeared to exhibit some dormancy or die-back in July.

Despite limited maintenance and no inputs of fertilizer or irrigation water, exceptional establishment and biomass production were noted in several cool-season grasses. With only monthly mowing to assist in eliminating weed infestation, most grasses established well with limited weed infestation by July 2006. Interestingly, a few grasses offered great color and appeal as well as weed suppression. We feel that certain tall and fine fescue cultivars as well native species such as creeping meadowgrass, crested wheatgrass and wild rye may also offer strong potential to provide attractive and competitive groundcovers in roadside settings. The fine fescues offer an advantage in that they require less mowing and can often be maintained without mowing on sloped, stress prone sites. Further research performed in roadside settings with high salt exposure, drought and poor soils will be needed to assess performance in more difficult conditions actually encountered along busy highways and paved roads. This research has proven to be of great interest to state Departments of Transportation wishing to update and enhance their recommendations for establishment of effective turfgrass and native grass mixtures based on performance in similar difficult settings. We are currently evaluating additional mixtures of native species and warm-season grasses to determine if these might show potential for introduction along roadsides in New York State. Many of these mixtures appear to establish readily when planted in early June, but their ability to overwinter and suppress weeds remains to be investigated.

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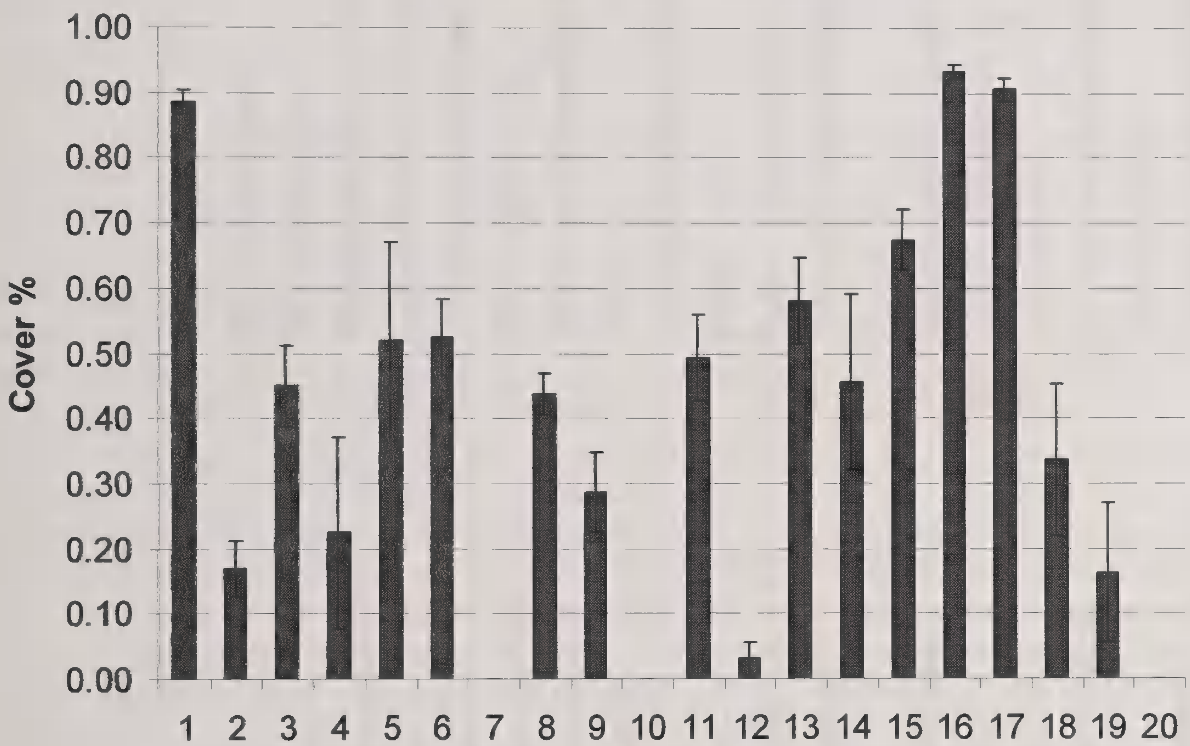
Table 1. Nineteen cool-season grasses evaluated at Ithaca NY under low maintenance management in 2006.

Treatment	Common Name	Cultivar	Scientific Name
1	Crested wheatgrass		*Agropyron cristatum (L.) Gaertn.*
2	Redtop		*Agrostis stolonifera L*
3	Creeping meadowgrass		*Poa pratensis L*
4	Smooth bromegrass		*Bromus inermis Lesser*
5	Streambank wheatgrass		*Elymus lanceolatus (Scribn. & J.G. Sm.) Gould*
6	Hard red fescue	No-mow	*Festuca rubra L.*
7	Arizona fescue		*Festuca arizonica Vasey*
8	Chewings fescue	Columbra	*Festuca rubra subsp. commutata L*
9	Chewings fescue	Intrigue	*Festuca rubra subsp. commutata L*
10	Chewings fescue	Sandpiper	*Festuca rubra subsp. commutata L*
11	Hard red fescue	Oxford	*Festuca rubra L.*
12	Hard red fescue	Reliant II	*Festuca rubra L.*
13	Hard red fescue	Fine Fescue Mix	*Festuca rubra L.*
14	Tall fescue	Tarheel II	*Lolium arundinaceum (Schreb.) S.J. Darbyshire*
15	Tall fescue	Rebel Exceda	*Lolium arundinaceum (Schreb.) S.J. Darbyshire*
16	Perennial ryegrass	Prelude	*Lolium perenne L.*
17	Russian wild rye		*Psathyrostachys juncea Nevski*
18	Weeping alkaligrass		*Psathyrostachys juncea Nevski*
19	Zoysiagrass	Zenith	*Zoysia japonica L*

Figure 1. a. Mean percentage of cover for crop and weeds in each grass species evaluated in the month of May. b. Mean percentage of cover for crop and weeds in each grass species evaluated in the month of June. c. Mean percentage of cover for crop and weeds in each grass species evaluated in the month of July. Means were calculated on the basis of eight replicates per treatment. Along the y axis, treatments 1 through 19 are the specific species or cultivars evaluated and are listed in table 1, in the same order. Treatment 20 is an unseeded control, which became later infested with turf and weedy grasses.

1a.



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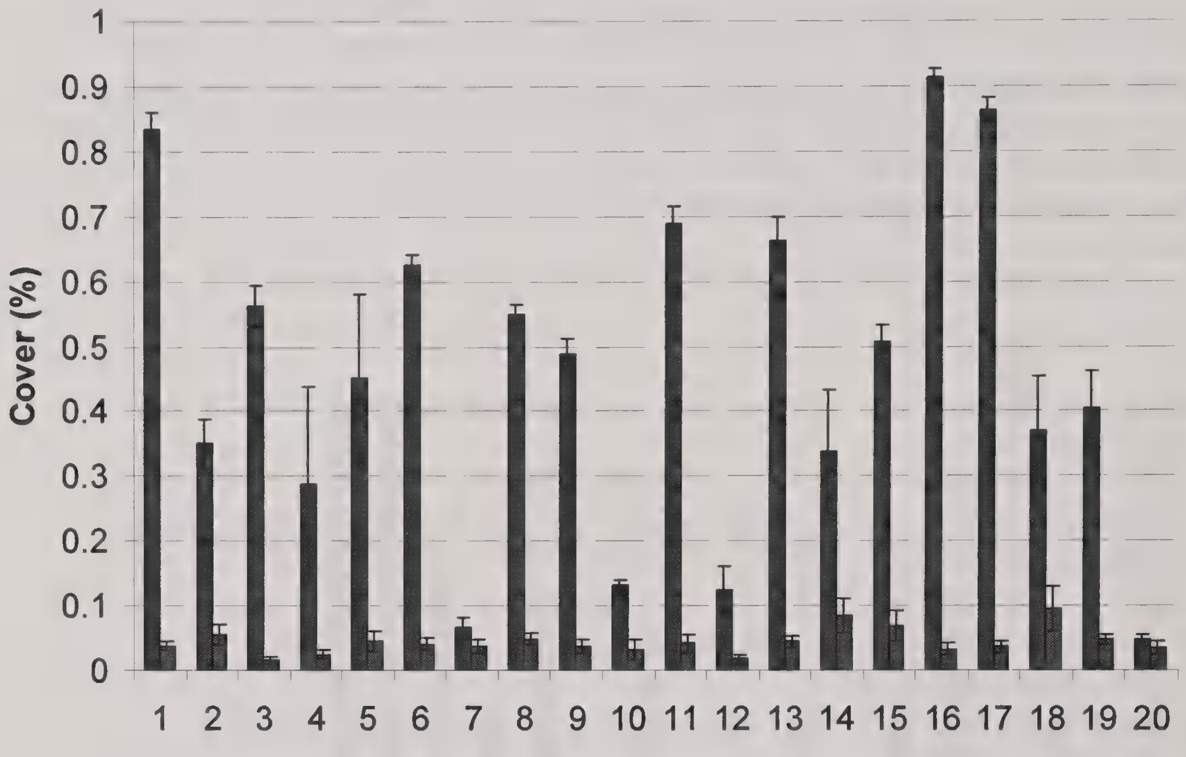
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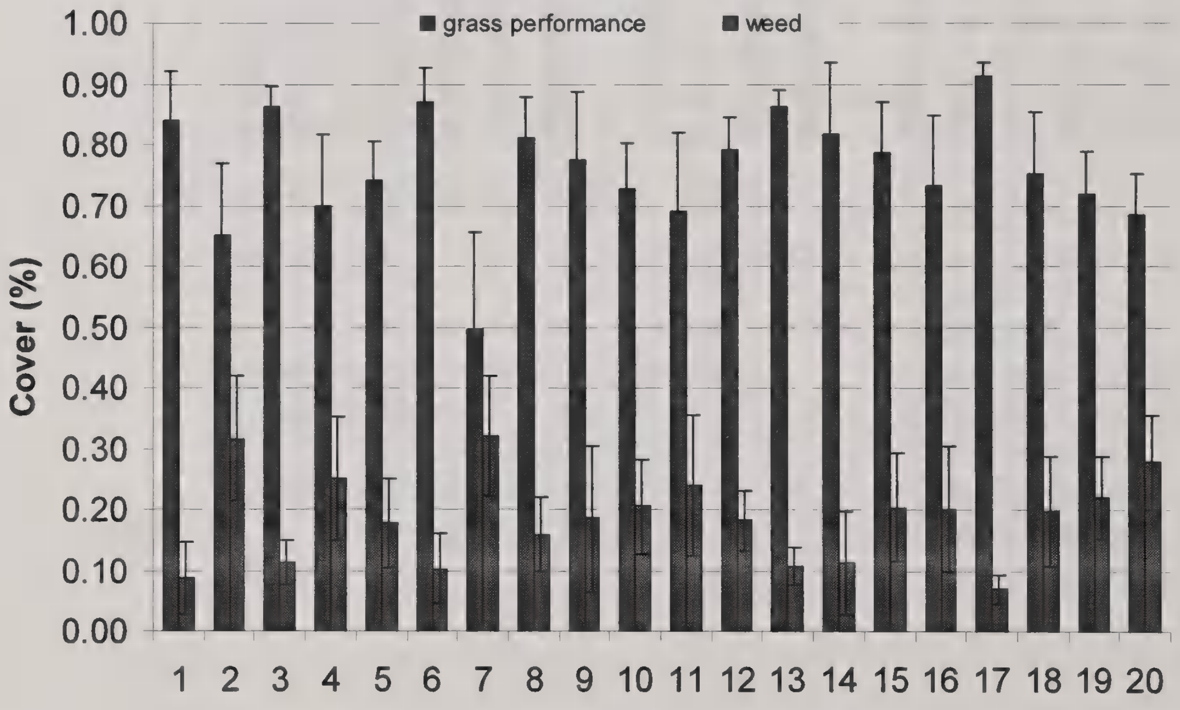
1c.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Cover (%)
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1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Seed Harvest and Processing

Equipment 'Outside the Box' Used to Harvest and Process Native Seed

Calvin L. Ernst

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This is an overview of some harvesting and processing equipment designed and utilized to handle some of nature's best seeds. This equipment has evolved from adopting conventional grain combines, cotton strippers, vacuum grain movers, brush machines, and debearders, to special harvesting and conditioning machines. The demand for large quantities of high quality seed requires the use of mechanical equipment. We have learned how to harvest seed from plants with stalks and leaves that are heavier than the seed they bare. We have added a vacuum to a combine stripper to collect the seed that drifts off of the header, as well as a chaff collector to save unthrashed seed heads from a conventional combine. A cotton picker turns into a vacuum row stripper for herbaceous seeds, and a stripper on a bi-directional tractor collects just about anything. A cushion grain-vac serves as a debearder when moving seed from grain bin to cleaner for large quantities of seed. A turning drum debearder allows for batch debearding of small seed lots. We have married a brush machine with a fractionalizing aspirator and screen machine to end all questions of our "thinking outside the box" ideas. At Ernst Conservation Seeds, we consider harvesting, drying, condition, and cleaning seed to be an art, not a science. If you don't try, you can't succeed.

Key words: Brush machine, debearder, stripper, vacuum row stripper

Australian Native Grass Seed Harvesting Equipment: Application in the Eastern United States

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Abstract

The use of native grasses is expanding in the United States and around the world. With this expansion innovative seed harvesters and harvesting systems are being developed. The objective of this paper is to demonstrate innovation seed harvesting machinery and techniques used in Australia, and show their potential application in the eastern U.S. Six different seed harvesters or harvesting systems will be described along with the advantages and disadvantages of each. The harvesters/harvest systems include: Modified Brush Harvester, Modified Cotton Harvester, Windrow/Chopper/Bin Harvesting System, Stafford Harvester, Scorpion Harvester, and Bushranger Harvester. One of the unique characteristics of these Australian harvesters is that three of the six use vacuum systems to actually strip the seed from the plant and/or to increase the efficiency of seed harvest and chaff separation. Similar designed harvesters may have tremendous application for eastern U.S. native grass species like little bluestem (*Schizachyrium scoparium* [Michx.] Nash.).

Key words: Australian grass seed harvesters, grass seed production, native grasses, native seed harvest

Introduction

There is tremendous interest in expanding the use of native grasses around the world. One of the greatest limitations to expanded use is successful seed production. An essential component of seed production is harvesting. The quantity of seed produced is irrelevant if it cannot be harvested. The objective of this paper is to describe innovative seed harvesting machinery and techniques used in Australia, and show their potential application in the eastern U.S.

Modified Brush Harvester

One harvester designed by Mr. Ian Chivers and his Australian company, Native Seeds Pty Ltd, is actually a modification of an off-the-shelf brush harvester sold by Prairie Habitats in Manitoba, Canada (Figure 1). The primary modification is the attachment of a collection bin on the front of the cowling. This has virtually eliminated the problem of seed being flicked up by the brush, hitting the cowling, and falling to the ground. The collection bin attachment collects these seed, while the remaining seed continue as before and flow over to the back of the brush and into the normal seed storage bin. The front collection bin is then cleaned separately. On virtually all the crops harvested with this attachment as much seed has been

collected in the front bin as in the back, thereby doubling seed yield from the same area. The modified brush harvester involves a simple modification that works extremely well and would be easy to add to brush harvesters currently sold in the eastern U.S.

Modified Cotton Harvester

Another harvester developed by Native Seeds Pty Ltd is a modified cotton harvester for native grass seed harvesting (Figure 2). The basic concept is to use the power, carrying and steering capacity of the cotton harvester for propulsion. Then the fan is used to create a suction force just behind the brush front and a pushing jet to the front of the brush. The pushing jet carries seedheads back into the brush while the suction helps to carry seed up the large tube to the bins. For reclining seedheads the fingers on the front bring them up and into the line of the pushing jets and onto the brush. The brush can rotate in either direction and at any chosen speed. It is powered by hydraulics from the motor. The brush is also adjustable within the harvesting front and can be set close to the bottom plate or at a distance of around 6" from the plate.

The bins at the back are unloaded to the side and are removable for cleaning. All seed and stems etc. are moved by air flow through the tube into the bins. The work of separating the clean seed from the chaff is done at a separate seed processing location. This unit is especially useful for field sizes over 20 acres because of field speed and large storage bin size. The unit shown in Figure 2 could easily be equipped with a larger header without running into capacity problems. There are obviously many used cotton harvesters in the eastern U.S. and with a bit of farm engineering similar units could easily be designed for native grass harvest.

Windrow/Chopper/Bin Harvester

This unit is currently under development by Native Seeds Pty Ltd. It will pick up windrows of cut crops and deliver them into a modified combine. It will be most useful for fluffy, shattering seeds to minimize seed loss during the harvesting process. The concept is a pick up belt (Figure 3) which brings all the material in the windrow back to an auger. The auger focuses the material into a space of around 3 feet in width, this then falls into a chopper which will turn the stems into small pieces, after which the material is carried by another auger into a bin or hopper. The seed itself is not chopped because of its small size, but it is simply propelled along with the chaff. The work of separating the clean seed from the chopped material is done at a separate seed processing location.

The advantage of this system is that it allows for the crop to ripen evenly in the windrow while it is in the windrow, where it is less susceptible to hot winds drying and shattering the crop. Obviously one can allow the crop to mature standing and then brush harvested, but the advantage of this system is the crop is only harvested once with good recovery rates. This system has already been used on the shatter prone Australian species wallaby grass (*Austrodanthonia* ssp.) and it worked very well. This system would be easily adapted in the eastern U.S. and may be most useful for small producers who could take the "chopped" material to a central seed processing facility.

Stafford Harvester

John Stafford of the Native Grass Resources Group in the Adelaide Hills of South Australia developed this harvester (Figure 4). It was one of the first locally designed

harvesters for native grasses in Australia and was designed specifically for *Austrodanthonia* ssp. and weeping grass (*Microaena stipoides* [Labill.] R. Br.). The hexagonal beaters revolve slowly forward and bend the heads over the black brush just above the orange bar. The brush revolves faster in the opposite direction (the front of the brush moves upwards) and strips the mature seed off and deposits it into the tray behind. This harvester has been further modified after the photo in Figure 4 was taken. Farmers in the eastern U.S. may want to try their hand at designing and constructing similar units.

Scorpion Harvester

Figure 5 shows the first version of the "Scorpion" harvester designed and built by Doug Seis of Rosevale Welding, NSW, Australia. It is a self propelled vacuum harvester and later versions have been mounted on a 4WD truck with the fan and bins on the bed, the collector in front, and the large tube going over the cab. A revolving brush has also been added to later versions to increase the versatility. This unit has worked extremely well with the primary advantages being the suction of chaffy seeds and the unique ability of the cone separating units to clean the seed. Eastern U.S. producers could easily design similar systems.

Bushranger Harvester

The harvester shown in Figure 6 was designed and built by Tony Wilson from Yass, NSW. Tony has built several different types. A major attribute of these units is their small size, so that they can be easily transported and can be offset behind a four wheeler. The Bushranger harvester is really just a vacuum unit, with later version having a revolving brush. A unique part of the design is a set of baffles that creates a ventura effect that effectively separates seed from chaff and stem material. This is another unit that small producers could develop in the eastern U.S.

Summary

Australia native seed producers have developed a number of unique harvesters that may have application for North American native grasses. We can learn a lot from the practicality and efficient design of these units. One of the unique design aspects is that three of the six harvesters shown use a vacuum system. Similar designed harvesters should have tremendous application for eastern U.S. species like little bluestem.

Figure 1. Modified Brush Harvester

Figure 2. Modified Cotton Harvester

Figure 3. Windrow/Chopper/Bin Harvester

Figure 4. Stafford Harvester

Figure 5. Scorpion Harvester

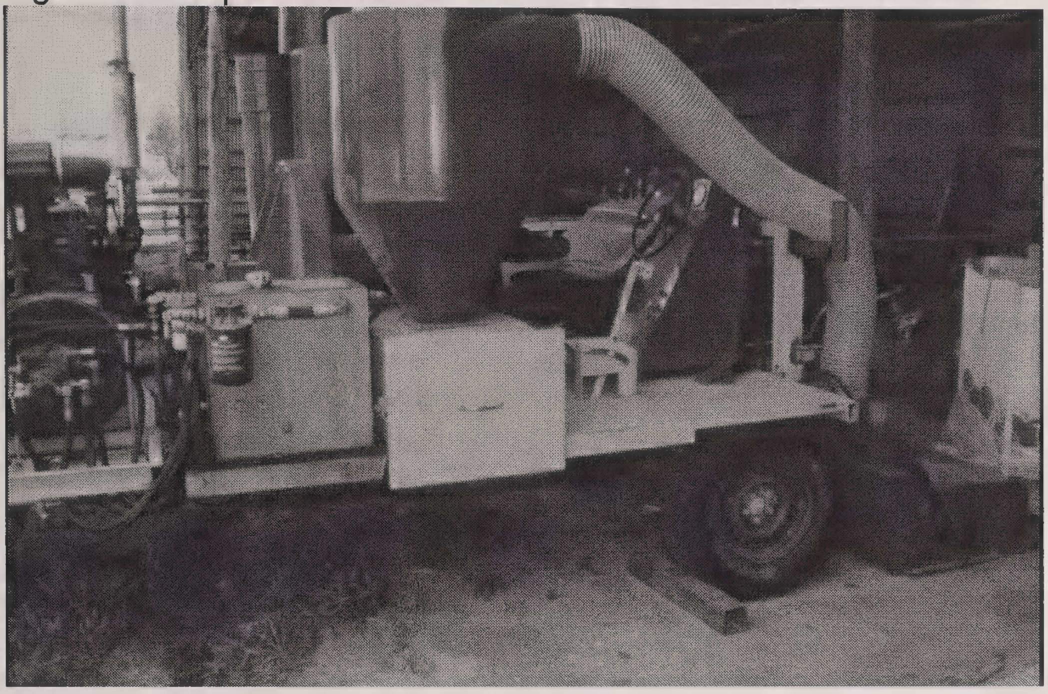

Figure 6. Bushranger Harvester

Wildlife Management

Changes in Grassland Establishment Practices by New York Department of Environmental Conservation in Western New York

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Grassland restoration efforts on Wildlife Management Areas (WMA) in the Lake Plains of New York have undergone a change in emphasis. In the mid-1980s, state agencies began experimental plantings of switchgrass (*Panicum virgatum* L.). This native warm-season grass showed promise as nesting and winter cover, predominantly for ring-necked pheasant (*Phasianus colchicus*). All warm-season grassland plantings on one WMA during a 14-year period from 1984 through 1997 were switchgrass, planted alone and at rates of 10 to 20 lb/ac. Monocultural stands of switchgrass are no longer being planted. This change in emphasis is due primarily to concern for conservation of grassland birds. More diverse mixes of native warm-season grasses initially replaced switchgrass. Recent plantings have also included native cool-season grasses. Seeding rates have also been reduced. Low-growing grasses in a mix of species with higher horizontal heterogeneity are favored over tall and less structurally diverse plantings.

Key words: Grassland birds, mixtures, structure, switchgrass

The Raritan Piedmont Wildlife Habitat Partnership: Developing a Landscape-Scale Grassland Restoration Plan for Threatened and Endangered Grassland Birds

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The Central Piedmont region of New Jersey formerly contained some of the most significant populations of grassland birds in the state. Vast acreages of large agricultural grasslands supported nesting populations of every rare grassland bird species in New Jersey. Over the past 25 years, many of the most significant nesting areas have been destroyed as the counties containing them have been transformed into the most rapidly developing counties in the state. This project seeks to implement the goals within the New Jersey Wildlife Action Plan by replicating the highly successful regional and national Joint Venture model established by the North American Waterfowl Management Plan at the local level. The Raritan Piedmont Wildlife Habitat Partnership (RPWHP) joins local and statewide non-governmental organizations, county, municipal, and state partners to effect conservation at a local, landscape-scale. The RPWHP pairs data on rare species occurrence and spatial analysis of existing habitat conditions contained within the New Jersey Landscape Project database with strategies for setting habitat and population goals established by national and regional upland bird conservation plans. This process provides a unique example both of implementation of the goals of State Wildlife Action Plans as well as landscape level conservation planning for grassland species.

Key words: Conservation planning, grassland birds, New Jersey

Vegetation Response to Management Practices on Two Hydric Sites Planted to Native Warm-Season Grasses in West Tennessee

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Native warm-season grasses (NWSG) are recommended for improving early successional wildlife habitat on areas enrolled in the Conservation Reserve Program (CRP). While NWSG establishment methods are relatively well documented, effective methods for managing established fields are less clear. Additionally, little is known about the effects of mid-contract management practices on NWSG in areas with hydric soil types. Six mid-contract management practices (fall disc, dormant season mowing, late spring disc, dormant season burn, late growing season burn, and an herbicide application) and a control were implemented on two previously unmanaged NWSG fields with hydric soils in west Tennessee in 2003-2004. Vegetation structure and composition were measured monthly throughout the growing season and once in the fall of 2004, then in the winter, and spring and throughout the growing season of 2005. Treatment differences were observed across all sampling periods. Results will be discussed in terms of wildlife habitat benefits of vegetation structure and composition.

Key words: CRP, wet soils, wildlife habitat

When is the Best Time to Disk Native Warm-Season Grasses for Wildlife?

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Abstract

Disturbance intensity, frequency, and timing affect the wildlife habitat potential of early successional plant communities. In addition to prescribed fire and other techniques, disking is recommended for managing established fields of native warm-season grasses (NWSG); however, seasonality of soil disturbance affects the composition of plant response. We evaluated the effects of dormant-season disking applied in December 2005, February, March, or April 2006 with and without applications of imazapic on resulting vegetation structure and composition in field planted with NWSG. All disking treatments decreased percent cover planted NWSG and increased bare ground and forb coverage. Undesirable warm-season grasses were increased by April disking, but remained similar to control in all other treatments. Although imazapic application reduced undesirable warm-season grass coverage and increased bare ground across all treatments, forb response and species richness decreased and percent cover of planted grass increased across all disking timings. We recommend relatively heavy dormant-season disking before March for improving early successional plant communities for wildlife. Imazapic herbicide may be used to effectively control undesirable grass weeds though some temporary trade-offs in wildlife habitat quality may result.

Key words: Bobwhite, disking, johnsongrass, native warm-season grass

Introduction

Early successional plant communities provide habitat for a variety of wildlife species. Quality early successional habitats in the South are characterized by a diversity of annual weeds, bunch-forming grasses, and shrubs, creating a community structure that is open at the ground level and maintained in a lower seral stage by periodic disturbance. Native warm-season grasses (NWSG) are commonly planted to enhance early successional wildlife habitats, especially when renovating sod-forming grasses (Washburn et al. 2000). However, when planted at high seeding rates or left unmanaged over time NWSG become rank and their habitat benefits are reduced (Jones et al. 2004).

Prescribed fire and disking are commonly recommended practices for managing early successional plant communities (Stoddard 1931, Rosene 1969). Periodic burning and disking increases bare ground and invertebrate abundance, improves plant community structure, and may increase coverage of desirable legumes and other forbs (Stoddard 1931, Rosene 1969, Hurst 1972, Manley et al. 1994). Although prescribed fire is an essential component of early successional habitat management, dormant season fires do little to alter plant composition in fields that have become dominated by perennial grasses. Relatively heavy disking reduces perennial grass density; however, resulting plant community composition and structure is effected by the timing of disking application (Olinde 2000, Carver et al. 2001, Madison et al.

2001, Greenfield et al. 2003). The plant community directly influences the availability of food and cover for wildlife. Therefore timing of soil disturbance affects the quality of wildlife habitat.

Past studies found fall disking stimulated desirable plants such as common ragweed [*Ambrosia artemisiifolia* L.], while disking later in the spring and early summer may increase undesirable plants such as sicklepod [*Senna obtusifolia* (L.) Irwin & Barneby] and nutsedge [*Cyperus esculentus* L.] (Squires 1989, Olinde 2000 Carver et al. 2001, Greenfield et al. 2003). Of particular concern are problems with undesirable warm-season grass weeds, such as johnsongrass [*Sorghum halepense* (L.) Pers.] crabgrass [*Digiteria sanguinalis* (L.) Scop.] and broadleaf signalgrass [*Urochloa platyphylla* (Munro ex Wright) R. Webster], associated with late-spring disking. Several studies have measured the effects of disking seasonality in the costal plain region (Olinde 2000, Carver et al. 2001) or in fields sown to tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire] (Madison et al. 2001, Greenfield et al. 2003). The objective of this research is to determine the best month(s) during the dormant season to disc in fields sown to NWSG by identifying the time period when plant species response shifts from desirable forbs to undesirable grasses and forbs. Additionally, we tested the effects of imazapic, an herbicide labeled for pre- and post-emergence control of undesirable grasses in NWSG, on plant community response to seasonal disking.

Methods

This research was conducted at Seven Islands Wildlife Refuge, a 410-acre area managed for early successional wildlife by the Seven Islands Foundation and Knox county Parks and Recreation. We applied disking treatments to a field planted in January 2004 with a mix of Rumsey indiangrass [*Sorgastrum nutans* (L.) Nash], Kaw big bluestem (*Andropogon gerardii* Vitman), and Aldous little bluestem [*Schizachyrium scoparinum* (Michx.) Nash] at a rate of 10 pounds of pure live seed (PLS) per acre. Prior to being sown to NWSG, primary land use was tall fescue pasture. Soils were sandy loams and clay loams with pH ranging from 5.5 to 5.9. Macronutrients phosphorus and potassium were in the low range.

We evaluated the effects of dormant-season disking applied in December 2005, February, March, or April 2006 with and without applications of imazapic on vegetation structure and composition. Treatments were applied in a strip-plot design with four replicates. Disking was conducted using an 8-foot hydraulic offset disc. The field was burned in January 2006 to facilitate disking. Plots were disked in 300 x 30-foot strips. At least six passes were used to thoroughly disturb the soil surface. Imazapic (Plateau, BASF Corp., 12 ounces per acre) was applied in April to 4 15 x 75-foot blocks within each strip using a backpack sprayer with a 6-foot hand boom with a total spray volume of 10 gallons of solution per acre. Non-ionic surfactant was added to spray at 0.25% of spray solution to increase efficacy of imazapic on emerged weeds in the plots disked earlier (December – March).

We measured vegetative response in June of 2006. We measured vegetation characteristics by systematically placing a 10.8 ft^2 sampling frame (Bonham 1989) at four locations within each treatment block. We estimated percent cover of total vegetative canopy, litter, and bare ground (sum = 100), and percent cover of vegetative canopy classes (sum ≥ 100) including forbs (broadleaf herbaceous plants), planted NWSG, undesirable warm-season grasses, cool-season grasses, brambles, sedges, and woody species to the nearest 5%. Additionally, we measured litter depth at the center of each sampling frame. We measured species composition using a 32.8-foot line transect (Canfield 1941) in the center of

each block. We measured the distance along each transect occupied by each plant. We identified plants to species where possible. We measured vegetation height at 0, 16.4, and 32.8 ft along each line transect. Plant species with a mean coverage < 2% of a treatment were combined into a miscellaneous category.

Data were analyzed as a strip plot design with treatments applied to plots (blocks) within strips (whole plot). We compared vegetation structure and composition among seasonally disked plots and control and among seasonally disked plots with and without imazapic. Several structural and compositional parameters failed to meet the assumptions of ANOVA. We used non-parametric statistics to test for treatment effects and compare among treatments. Following detection of treatment effects ($p \leq 0.05$) using a Kruskal-Wallis test (SAS PROC NPAR1WAY) we made comparisons among treatments using Tukey's multiple comparison of the ranks (PROC RANK; PROC GLM) or Wilcoxon-Mann-Whitney two sample test (PROC NPAR1WAY).

Results

Timing of disking

We detected treatment differences for percent canopy cover of planted NWSG (Chi-square=39.61, df=4, *P*<0.0001), undesirable warm-season grass (Chi-square=23.00, df=4, *P*<0.0001), forb (Chi-square=37.17, df=4, *P*<0.0001), and bare ground (Chi-square=239.70, df=4, *P*<0.0001) as well as vegetation height (Chi-square=14.10, df=4, *P*<0.0.007) and species richness(Chi-square=11.87, df=4, *P*<0.0184; Table 1). All disking treatments decreased percent cover planted grass and increased bare ground. Percent forb coverage was increased by all disking timings. Undesirable warm-season grasses were increased by April disking, but remained similar to control in all other treatments. Species richness was increased by disking in March.

We recorded 52 total plant species across all treatments. We detected treatment effects (Kruskal-Wallis *P*<0.05) for 8 plant species (Table 2). December and February treatments increased common ragweed. Disking treatments also increased coverage of lanceleaf plantain [*Plantago lanceolata* L.]. Disking in April increased johnsongrass. All disking treatments decreased coverage of big and little bluestem and indiangrass.

Imazapic effects

We detected treatment differences of imazapic across all disking treatments (Table 3). Imazapic application decreased forb response and species richness and increased percent cover of planted grass and bare ground across all disking timings. Additionally, imazapic application reduced undesirable warm-season grass coverage across all treatments.

Imazapic reduced coverage of common ragweed and lanceleaf plantain across all disking treatments. Coverage of big and little bluestem and indiangrass was increased by imazapic (Table 4). Johnsongrass coverage was decreased in the March and April disking treatments following imazapic application.

Discussion

These data support the recommendation that disking should not be conducted after March in areas where undesirable warm-season grass weeds may be a problem. Disking in December and February greatly increased coverage of common ragweed, a desirable wildlife plant because of its structure, seed production, and forage potential. All disking treatments

decreased planted NWSG coverage and increased forb coverage and bare ground compared to control, indicating that disking during any time improved the structural and compositional aspects of a dense NWSG field for many wildlife species.

Imazapic herbicide effectively reduced undesirable warm-season grass coverage in March and April disking treatments; however, imazapic reduced coverage of forbs and species richness across all treatments, reducing the beneficial effects of disking. Imazapic significantly increased bare ground in all, but the December treatment. Imazapic was applied in April, pre-emergence for the April treatment, but post-emergence (with surfactant) in all other treatments. Imazapic has different weed control properties when applied pre-emergence as opposed to post-emergence. Vegetation resulting from imazapic applications after disking may have been different if all treatments were applied pre-emergence. Additionally, a lower rate of imazapic (Plateau, BASF Corp., 6-8 ounces per acre) could be used to control undesirable grass weeds and may have less impact on desirable forbs. We applied imazapic at the maximum labeled rate (Plateau, BASF Corp., 12 ounces per acre) to achieve the greatest weed control effects.

Results from this study are consistent with results from other studies conducted in areas where soil and seed bank properties differ from those on our study area. Carver et al. (2001) found fall disking (October – November) in north Florida increased coverage of common ragweed and brambles (*Rubus* spp.), while spring disking (March – April) increased undesirable species. Research in Louisiana found disking in November or February resulted in increased bobwhite food plant production as opposed to disking in May (Olinde 2000). Fall-disked fields dominated by ragweed were used extensively by bobwhite broods in Georgia (Yates et al. 1995). Jones et al. (1993) found similar plant response from disking in November and March in the Piedmont of South Carolina. Disking in June significantly increased crabgrass coverage (Jones et al. 1993). Several studies report an initial increase in desirable response from soil disturbance in the first growing season post-treatment with desirable effects declining greatly in the successive growing seasons (Jones et al. 1993, Madison et al. 2001, Greenfield et al. 2003). Additionally, plant community response to disking may be unsatisfactory in areas where the seed bank has been altered by several years of rowcrop agriculture (Squires 1989, Greenfield et al. 2003). While these studies indicate a preference for fall disking, they fail to identify when desirable plant community response shifts towards undesirable weed species.

We recommend relatively heavy disking from October until February for enhancing fields of NWSG for wildlife in Tennessee. Disking and burning should be implemented on a 2 to 4-year rotation to maintain the structure and composition preferred by many early successional obligate wildlife species. Managers should not “tread lightly” when managing fields with potential weed problems as the benefits of disking far out weight the potential weed problems that may ensue. Weed problems should be approached actively and addressed with proper control methods as needed. Undesirable grass weeds may be controlled with imazapic and other herbicides, such as glyphosate and clethodim. Undesirable broad-leafed weeds may be controlled with herbicides such as dicamba, 2-4D, and 2-4,DB. Short-term negative effects from herbicide applications are mitigated by long-term habitat benefits of controlling undesirable weeds.

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Table 1. Mean and standard error (SE) of vegetation structural characteristics exhibiting treatment effects (Kruskal-Wallis P ≥ 0.05) among seasonally disked plots and control in a NWSG field in Knox County, Tennessee.

Treatment	Control			December			February			March			April		
	x	SE		x	SE		x	SE		x	SE		x	SE	
Planted[1] (%)	96.8	(1.4)	A	68.7	(5.7)	B	55.0	(5.6)	B	49.4	(2.8)	B	57.8	(6.6)	B
Forb(%)	22.2	(4.0)	B	59.3	(6.4)	A	70.9	(5.2)	A	77.5	(3.4)	A	41.5	(7.2)	A
WSG(%)[2]	11.9	(5.0)	B	7.5	(2.8)	B	15.3	(5.4)	B	15.9	(3.6)	B	43.8	(6.9)	A
Bare(%)	0.6	(0.6)	C	15.6	(1.8)	B	18.1	(3.2)	B	18.1	(2.4)	B	30.3	(4.0)	A
Height(in)	31.9	(2.0)	A	24.0	(0.8)	AB	24.1	(2.9)	AB	13.5	(1.8)	C	18.7	(2.3)	BC
Richness[3]	9.2	(1.6)	B	14.0	(0.4)	AB	13.0	(0.4)	AB	16.5	(1.2)	A	12.0	(1.3)	AB

[1] Percent cover of planted NWSG including big and little bluestem and indiangrass.
[2] Percent cover of undesirable warm-season grasses such as johnsongrass and crabgrass.
[3] Species richness based on total number of species per 32.8-foot line transect.
[4] Numbers within rows followed by the same letter are not different; Tukey's multiple comparison of the ranks.

Table 2. Comparison of mean and SE for vegetation species composition among seasonally disked plots and control in a NWSG field in Knox County, Tennessee.

Species	Kruskal-Wallis	Control		December		February		March		April	
		x	SE	x	SE	x	SE	x	SE	x	SE
Andropogon gerardii	0.0461	5.6[1]	(0.7)	3.8	(0.9)	3.8	(0.4)	3.0	(0.1)	3.0	(0.3)
Acalypha virginica	0.2621			0.4	(0.2)	0.2	(0.1)	1.0	(0.6)	1.2	(1.0)
Ambrosia artemisifolia	0.0173	0.4	(0.1)	3.7	(0.6)	4.0	(0.8)	2.2	(0.9)	1.8	(0.5)
Cyperus esculentus	0.3711					0.0	(0.0)	0.4	(0.3)	0.3	(0.2)
Equisetium arvense	0.9510	0.4	(0.2)	0.3	(0.1)	0.3	(0.1)	0.2	(0.1)	0.6	(0.4)
Oxalis stricta	0.0414			0.6	(0.2)	0.1	(0.0)	0.6	(0.3)	0.1	(0.1)
Plantago lanceolata	0.0301	0.1	(0.1)	2.2	(1.4)	1.7	(0.4)	1.9	(0.5)	0.6	(0.2)
Schizachyrium scoparium	0.0178	1.6	(0.1)	0.5	(0.2)	0.8	(0.4)	0.4	(0.2)	0.0	(0.0)
Setaria pumila	0.6281	0.0	(0.0)	0.2	(0.0)	0.6	(0.3)	0.2	(0.1)	0.4	(0.2)
Sorghum halepense	0.0079	0.0	(0.0)					0.7	(0.1)	1.8	(1.4)
Sorgastrum nutans	0.0091	5.8	(0.6)	4.4	(0.3)	2.0	(0.3)	3.4	(0.6)	2.2	(0.6)
Trifolium pretense	0.0346	0.2	(0.1)	0.1	(0.1)	0.8	(0.2)	0.2	(0.1)	0.0	(0.0)
Miscellaneous	0.1635	0.5	(0.2)	1.8	(0.4)	1.3	(0.5)	2.6	(0.7)	2.3	(0.5)

[1] Mean coverage in meters for each species recorded along 32.8-foot line transects (N=4).

Table 3. Mean vegetation structural characteristics among seasonally disked plots with and without imazapic in a NWSG field in Knox County, Tennessee.

Treatment	December			February			March			April		
	No[1]	Yes[2]	*P*[3]	No	Yes	*P*	No	Yes	*P*	No	Yes	*P*
Planted(%)[4]	68.7	83.8	0.0572	55.0	76.9	0.0145	49.4	88.1	0.0020	57.8	81.5	0.0091
Forb(%)	59.3	25.9	0.0002	70.9	37.8	0.0039	77.5	17.8	<0.0001	41.5	14.1	0.0023
WSG(%)[5]	7.5	1.8	0.0870	15.3	4.7	0.0109	15.9	1.9	0.0013	43.8	9.7	0.0002
Bare(%)	15.6	21.6	0.2507	18.1	30.3	0.0278	18.1	34.7	0.0020	30.3	48.8	0.0031
Height(in)	24.0	21.3	0.5526	24.1	24.8	0.9999	13.6	18.7	0.0284	18.7	11.8	0.0284
Richness[6]	14.0	7.3	0.0284	13.0	4.0	0.0284	16.5	5.0	0.0408	12.0	4.5	0.0323

[1] No imazapic application
[2] Imazapic applied at 12 ounces per acre in April 2006.
[3] Wilcoxon-Mann-Whitney *P*-value for H_0 no imazapic = imazapic within month of disking
[4] Percent cover of planted NWSG including big and little bluestem, and indiangrass.
[5] Percent cover of undesirable warm-season grasses, such as johnsongrass and crabgrass.
[6] Species richness based on mean number of species per 32.8-foot line transect.

Table 4. Comparison of mean vegetation species composition among seasonally disked plots with and without imazapic application in a NWSG field in Knox County, Tennessee.

Species	December			February			March			April		
	No[1]	Yes[2]	*P*[3]	No	Yes	*P*	No	Yes	*P*	No	Yes	*P*
Andropogon gerardii	3.8[4]	4.4	0.7728	3.8	5.4	0.0433	3.0	5.9	0.0209	3.0	3.0	0.5637
Acalypha virginica	0.4	0.0	0.0472	0.2			1.0	0.0	0.1215	1.2	0.1	0.3211
Ambrosia artemisifolia	3.7	0.3	0.0209	4.0	0.0	0.0139	2.2	0.2	0.0833	1.8	0.2	0.0202
Cyperus esculentus				0.0			0.4			0.3		
Equisetium arvense	0.3	1.0	0.0294	0.3	0.2	0.0394	0.2	0.4	0.1102	0.6	0.6	0.4568
Oxalis stricta	0.6			0.1			0.6			0.1		
Plantago lanceolata	2.2	0.0	0.0139	1.7	0.0	0.0139	1.9	0.0	0.0139	0.6	0.0	0.0472
Schizachyrium scoparium	0.5	0.7	0.5637	0.8	1.2	0.5637	0.4	0.2	0.4568	0.0	0.1	0.8501
Setaria pumila	0.2			0.6	0.0	0.0472	0.2			0.4	0.1	0.5083
Sorghum halepense							0.7	0.0	0.0139	1.8	0.4	0.0477
Sorgastrum nutans	4.4	5.2	0.3865	2.0	2.8	0.4678	3.4	3.3	0.9889	2.2	3.6	0.0833
Trifolium pratense	0.1	0.4	0.5385	0.8	0.1	0.0180	0.2	0.0	0.1663	0.0		
Miscellaneous	1.8	0.3	0.0202	1.3	0.0	0.0139	2.6	0.1	0.0180	2.3	0.1	0.0202

[1] No imazapic application
[2] Imazapic applied at 12 ounces per acre in April 2006.
[3] Wilcoxon-Mann-Whitney *P*-value for H_0 no imazapic = imazapic within month of disking application for each structural parameter.
[4] Mean coverage in meters for each species recorded along 32.8-foot line transects (N=4).

Effects of Mid-Contract Management Practices on Monoculture Switchgrass Stands in CREP

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Mid-contract management is a required component of all new Conservation Reserve Program (CRP) and Conservation Reserve Enhancement Program (CREP) contracts to retain the resource values of established cover. We evaluated the effects of six proposed mid-contract management practices on switchgrass stands and ground level physical characteristics. We conducted two replications for each practice, sampling 10 random 1-m plots in each practice replication to evaluate vegetation cover and density. Robel pole measurements were taken at each plot center to evaluate visual characteristics. We anticipate significant differences for plant density, visual obstruction, and forb and bare ground frequency between mid-contract practices and controls. Preliminary data show that the best mid-contract management tools for switchgrass were to mow during the dormant season and then disk lightly or spray a full rate of glysophate (2 quarts/acre) in late May.

Key words: Conservation Reserve Enhancement Program, glyphosate, stand management

Grasslands for Wildlife: A Program of the New York State Department of Environmental Conservation

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The ring-necked pheasant (*Phasianus colchicus*) population in New York declined sharply in the mid 1970s. Lack of secure nesting and brood-rearing habitat is thought to be responsible for the decline. Results from an experimental habitat project in western New York proved that increasing the quantity of fallow grasslands by 5% greatly increased pheasant populations compared to untreated or control areas. In 1999, the New York State Department of Environmental Conservation adopted *A Ten-year Management Plan for Ring-necked Pheasants in New York.* To encourage the establishment of grasslands for pheasants, a program was developed that allocates $10,000 annually to purchase grass seed. The seed is distributed to private landowners and planted to provide long-term grassland cover. The program is called “Grasslands for Wildlife.” Objectives of the program include the purchase of $10,000 of native warm-season grass seed, establishment of grasslands 5 - 40 acres in size in our best pheasant range, formation of partnerships with organizations interested in pheasants and other grassland wildlife, and to increase public awareness about the value of grasslands. Since 2001, 18 grassland sites have been established on 313 acres. The sites range from 3 to 50 acres in size and each site is identified by a “Grasslands for Wildlife” sign. Different mixtures of native warm-season grasses have been planted, but the predominant species are switchgrass (*Panicum virgatum* L.), Indiangrass (*Sorghastrum nutans* L Nash.), Eastern gamagrass [*Tripsacum dactyloides* (L.) L], and big bluestem (*Andropogon gerardii*Vitman). Partners include private landowners, Pheasants Forever and the USDA Natural Resources Conservation Service.

Key words: Awareness, grasslands, partners, pheasants

The Pennsylvania Conservation Reserve Enhancement Program providing Native Grassland Habitat for Wildlife

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The Conservation Reserve Enhancement Program (CREP) was designed to address critical resource issues on a watershed basis. The Pennsylvania CREP, now composed of two agreements and an amendment, was initiated in April of 2000 and encompasses 59 of the 67 counties in the Commonwealth, targeting 265,000 acres in the Susquehanna, Potomac, and Ohio River watersheds. Pennsylvania's CREP was the first to include upland Highly Erodible Land (HEL), and now targets 220,000 acres for HEL upland conservation practices to improve water quality, reduce soil erosion, and provide secure nesting cover for grassland nesting birds. Most grassland nesting bird populations in Pennsylvania have declined by over 80% in the past 40 years due to loss of habitat to development and increasingly intensive farming practices. To encourage landowners to enroll HEL in CREP and plant native grasses, the United States Department of Agriculture (USDA) and Commonwealth of Pennsylvania provide 10-15 year contracts with an annual enhanced rental rate and 100% reimbursement for establishment of native grasses. In addition, the PA Game Commission (PGC) provides a one-time signing incentive for native grass to their private land access cooperators that is equal to the base rental rate. To ensure that equipment is available to plant the native grass, the PGC acquired 28 native grass drills to lend to landowners, while non-governmental organization partners and custom operators provided another 16 native grass drills. As of June 2006, over 30,000 acres of native grass have been established through the PA CREP, and over 120,000 acres of total grasslands have been established and managed for grassland nesting birds. In addition, over 5,000 acres of native grass and 15,000 of other grasses will be planted in 2007.

Key words: CREP, grassland birds, native grass, Pennsylvania,

New Jersey Habitat Incentive Team: A Collaborative Approach for Wildlife Habitat Creation, Restoration and Management in New Jersey

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Abstract

The New Jersey Habitat Incentive Team (NJ HIT) began on November 1, 2004 through a meeting among federal and State resource agencies and non-profit organizations. The mission of NJ HIT is to promote fish and wildlife habitat restoration in New Jersey through a cooperative and collaborative approach using the multiple programs offered by its members. The NJ HIT current members include: U.S. Fish and Wildlife Service (USFWS), Natural Resources Conservation Service (NRCS), Farm Service Agency, New Jersey Division of Fish and Wildlife (NJDFW), NJ Audubon Society (NJAS), Conserve Wildlife Foundation (CWF), Quail Unlimited, Trout Unlimited, National Wild Turkey Federation, The Nature Conservancy, Ruffed Grouse Society, Ducks Unlimited, and Conservation Resources, Inc. To meet our mission, the one goal of the NJ HIT is to hire several regional private lands biologists. The purpose of these biologist positions is to provide “one-stop shopping” for landowners to design, plan, and coordinate available programs to implement and fund habitat restoration and management. The programs available to landowners are typically administered through individual agencies (USDA/NRCS Farm Bill programs, NJDFW Landowner Incentive Program, and USFWS Partners for Fish and Wildlife) and the NJ HIT concept is to have a single private lands biologist work with a landowner to design, plan and secure funding from appropriate programs to implement projects (e.g., grassland creation, restoration and management). Presently, NJ HIT worked cooperatively to hire two private lands biologists through funding from NJDFW, NRCS, NJAS and CWF to implement on-the-ground projects.

Key words: Funding, grasslands, habitat restoration, programs

Introduction

The concept of collaboration among resource agencies with shared goals and programs has been implemented in New Jersey for more than a decade. The USFWS through the Partners for Fish and Wildlife Program and the NRCS through various Farm Bill programs have been cooperating on habitat restoration projects since 1991. A Memorandum of Agreement (MOA) between the two agencies identified their shared vision and efforts, but beyond that cooperation was on a project-by-project basis. In 2004, the NJDFW's new Landowner Incentive Program created an opportunity for State and federal agencies, as well as several non-profit organizations, to cooperate on projects in a more focused manner through shared goals and contribution agreements. The sharing of resources and effort resulted in the establishment of the NJ HIT, which has enabled federal and State agencies

and non-profit organizations to "buy-in" to a shared vision of habitat restoration in New Jersey.

The combined efforts resulted in a project that is attractive and fundable to foundations and grant sources. Two private lands biologists have been hired using funds from NRCS, DFW, National Fish and Wildlife Foundation, NJAS and CWF. The NJAS, using various grant sources, also hired two additional conservation biologists that are also part of the NJ HIT. Working on-the-ground, the biologists enabled each agency to realize large benefits through this cooperative effort (in just two years, nearly 2,000 acres are being managed for grassland birds through delayed mowing and almost 1,000 acres of that will be restored to native warm-season grass).

Moreover, the NJ HIT members determined that the development of habitat focal areas would direct our activities to restore and manage larger tracts of habitat. The first focal area habitat was grassland and NJ HIT developed a statewide potential grassland focal area map using Geographical Information Systems (GIS) layers. Ideally the regional private lands biologists would use this information to reach out to landowners within these important focal areas thereby restoring and managing habitat for area sensitive grassland bird species. The NJ HIT potential grassland focal area map has been used as a base layer for a local habitat protection effort in New Jersey. The NJ HIT will also be working on a wetland, scrub/shrub, and riparian focal area maps for New Jersey in the near future. These focal areas are critical in directing habitat restoration efforts by NJ HIT.

Challenges

All organizations participating in the NJ HIT have an interest in habitat restoration and the application of this restoration to private and public lands in New Jersey. However, one of the challenges of this association was determining which organizations had something to offer toward implementation of habitat restoration (e.g., funds, equipment, labor, land, in-kind technical support, etc.) and those organizations that simply wanted to provide input. The NJ HIT was formed based on the theory that all organizations at the table would offer something tangible toward actual on-the-ground habitat restoration. The priority for the NJ HIT is to *implement* habitat restoration, not form another forum for discussion of policy and planning of habitat restoration.

The NJ HIT also recognized that each organization involved has different set of goals or objectives that direct their interests or mission. Some organizations are species specific (e.g., Quail Unlimited, Pheasants Forever, National Wild Turkey Federation) while others have broader interests (e.g, Ducks Unlimited, New Jersey Audubon Society) and some organizations are focused primarily on private lands (USFWS and NRCS), while others are focused primarily on public lands (NJDFW). The challenge with the NJ HIT is to support and implement on-the-ground habitat restoration by bringing together our common interests and goals while accepting our different objectives.

Creating an all-inclusive, efficient program delivery mechanism for NJ HIT private lands biologists for habitat restoration has also been a challenge. The three major agencies that have funding programs available to landowners, USFWS, NRCS, and NJDFW have specific institutional rules and policies that direct funds, agreements, equipment use, and staff time. These institutional barriers have been a challenge to combining efforts with multiple agencies and organizations. However, NJ HIT was not formed to replace, reinvent, or supplant existing programs, but to provide a single, knowledgeable resource to a landowner

to direct restoration and management efforts. The NJ HIT tackled that obstacle by gaining buy-in from those agencies through training of the NJ HIT biologists using agency staff and existing paperwork. The skepticism of agency administrators has diminished over time due to our success in working together and thereby helping each agency meet their goals. The NJ HIT focuses on the strengths of these programs and through collaboration, can deliver more habitat restoration than any one of these programs individually.

Discussion

Partnership is a frequent “buzzword” used by agencies and organizations. The NJ HIT is partnership at work and clearly demonstrates that an effective and efficient partnership really is the most substantial method of implementing habitat restoration. No single organization or agency can accomplish as much as many organizations combined with a shared vision. The NJ HIT formed only two years ago and despite the challenges has accomplished a great deal. Although NJ HIT’s work to date has focused primarily on grassland restoration (e.g., establishment of warm-season grasses), the NJ HIT has been responsible for the restoration of approximately 1,116 acres of grassland and 35 acres of wetlands in two years. This program has also been the impetus for the hiring of two private lands biologists and the cooperative use of four no-till grass drills.

The NJ HIT biologists meet on a regular basis to discuss issues, challenges, and needs they encounter in the field and during implementation of plans. The biologist group consists of biologists from NRCS, FSA, USFWS, NJ Dept. of Agriculture, NJDFW, NJAS, CWF, and National Turkey Federation. The sharing of ideas, concerns and solutions has helped cement positive relationships and solve problems in the field. Each biologist brings unique set of skills and experience and by utilizing them as a group, NJ HIT has become a powerful source of information and resources for the landowner. The biologists in turn are educated about other agency programs resulting in the best bang for the buck for both the landowner and the habitat. It is this collaboration that has resulted in New Jersey’s huge success in restoring and managing habitat for declining species.

To summarize, the NJ HIT is valuable because it leverages program funding and resources while strengthening relationships between agencies and groups to get more habitat restoration projects completed. The NJ HIT truly represents partnerships, collaboration, and cooperation to implement habitat restoration through shared goals and objectives.

Use of a Citizen Science Approach to Evaluate the Effects of Habitat Management on Grassland Bird Populations

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We developed a monitoring protocol that establishes a measure of success and allows evaluation of enrolled farmland for response by target grassland bird species to habitat management regimes. Furthermore, managed grasslands can be evaluated by employing the assistance of trained volunteers. Our evaluation includes: 1) a standardized survey of grassland habitats to determine baseline information on abundance and distribution of target grassland species prior to enrollment in conservation programs, 2) follow-up surveys after completion of habitat creation or enhancement to determine if management was successful in providing improved grassland bird habitat, and 3) recommendations for adjusting approach to better refine utilization of Farm Bill programs and the Landowner Incentive Program (LIP) to best benefit target species. Thus, we can collect information from control and managed grasslands to assess the response of breeding birds and vegetation to grassland habitat restoration and enhancement, and can use that information in an adaptive management process. We conducted our first survey in spring 2005 by recruiting and mobilizing approximately 50 volunteers through New Jersey Audubon Society's Citizen Science Program to perform fixed radius point counts for grassland-dependent species at 342 predetermined points along 28 previously established roadside routes. This preliminary information allows us to develop a baseline data set, (and to compare current population and habitat conditions to those measured during surveys conducted in the 1980s and 1990s). A total of 452 individuals from eight species of grassland birds were observed. Most abundant were Eastern Meadowlark, with 147 individual observations at 51 points and Bobolink, with a total of 156 individual observations at 49 points. Species less frequently encountered were Savannah and Grasshopper Sparrow, with 48 and 45 individuals of each observed during the survey period. In 2006 we expanded our program to include new and one-year post management LIP sites (30 sites/72 points), new WHIP sites as well as ones that are 4-5 years post management (13 sites/21 points), and a subset of the roadside sites surveyed in 2005 (27 routes/200 points). Our volunteers are currently completing these surveys. The involvement of Citizen Scientists enables the collection of the required information without using additional staff resources. Furthermore, this additional community outreach aspect provides the opportunity for the lay person to be directly involved in and better understand land management issues, even when they do not directly affect their own property.

Key words: Bird monitoring, bobolink, eastern meadowlark, savannah sparrow

The Use of Conservation Reserve Enhancement Fields by Grassland Birds in Southern Pennsylvania

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In 2000 a federal program, the Conservation Reserve Enhancement Program (CREP) was initiated in 20 counties in south-central Pennsylvania to offer farmers the opportunity to take highly erodible and environmentally sensitive land out of production, thereby improving water quality, reducing soil erosion and increasing grassland, wetland and riparian habitat for wildlife. From 2001-2004 we surveyed birds on 114 randomly selected CREP fields, ranging in size from 5 to 69 acres. Nesting birds were monitored on 73 of those fields, and a subset was compared with paired hayfields, with the aim of describing the bird community using CREP fields, and assessing nesting success. Based on both density estimates of singing males and the densities of nests located, Red-winged Blackbird was the most numerous species in CREP fields, while Grasshopper Sparrow and Eastern Meadowlark were the most common grassland specialist species. A total of 31 species were identified during the surveys and we found a total 969 nests of 19 different species in CREP fields, indicating that CREP has provided a valuable new nesting habitat for farmland and grassland birds in the region. Species diversity, population densities and nest success were higher in CREP fields than in hayfields. Nest success was similar to that found in other studies in grasslands across North America.

Key words: CREP, eastern meadowlark, grasshopper sparrow, red-winged blackbird

Bird population responses to the Conservation Reserve Enhancement Program in Southern Pennsylvania

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Abstract

Grassland bird populations have decreased significantly across North America in recent decades. It is considered that the new grasslands created under the Conservation Reserve Program (CRP) have benefited grassland birds, although most species continue to decline. An enhanced version of CRP, the Conservation Reserve Enhancement Program (CREP) was introduced in southern Pennsylvania in 2001. A monitoring program was established in 2001 to assess the effects of the program on populations of grassland and other birds. Data from the bird monitoring program show that some grassland birds have continued to decline, but that others increased during the period 2001-2005. Populations of several grassland species fared better in areas where a higher percentage of farmland was enrolled in CREP. The strongest positive effects of CREP on grassland bird populations were noted for American Kestrel and Eastern Meadowlark, with evidence of at least some positive response for another seven species. These responses are early indicators that CREP has benefited some grassland bird species in southern Pennsylvania, but we caution that the program is still in its infancy and that responses for some species may show a considerable time-lag due to the small and fragmented nature of grassland bird communities in the region.

Key words: CREP grassland, grassland birds, monitoring, Pennsylvania

Introduction

Grassland bird populations have been in steady decline across North America for the past four decades or more (Vickery 2001; Sauer et al. 2005). The declines are of such magnitude that they have been predicted to become a "prominent wildlife conservation crises of the 21st Century" (Brennan and Kuvlesky 2005). The causes of these declines are many and varied. Loss of grassland extent and habitat fragmentation have undoubtedly been major contributory factors, but changes in grassland management, such as increased frequency of earlier mowing, and replacement of native grassland with monocultures, often of non-native species, are also important. This intensification of grassland and other agricultural management is acknowledged to have had adverse environmental impacts. To negate some of these impacts, the Conservation Reserve Program (CRP) was introduced in the 1985 Food Security Act, with key aims of curtailing excess agricultural production and reducing soil erosion (Isaacs and Howell 1988). The CRP requires that farmers take erodable land out of arable production and sow grass, for contract periods of 10-15 years, in return for a rental income. The CRP resulted in the creation of millions of acres of grasslands across agricultural areas of the United States. Numerous studies have shown that the new habitat created by CRP has benefited grassland bird species (e.g. Johnson and Igle 1995, Ryan et al. 1998, Swanson et al.1999), but most grassland bird species have continued to decline

since the introduction of CRP (Norment 2001), suggesting that it has not been sufficient to compensate for continuing population losses across the farmed landscape.

Due to unfavorable local economic conditions, CRP enrollment was low in the northeast United States. In order that the program be more suitable for those areas, a subsidiary program, the Conservation Reserve Enhancement Program (CREP) was authorized in the 1996 Farm Bill.

In April 2000, the Governor of Pennsylvania and U.S. Secretary of Agriculture approved a $210M conservation initiative for 20 counties within the Lower Chesapeake Bay watershed in southern Pennsylvania. The Pennsylvania Conservation Reserve Enhancement Program has a goal of converting 100,000 acres of cropland and marginal pasture to conservation cover for 10-15 years. The program's goals are to improve water quality, reduce soil erosion, increase farm income, and improve wildlife habitat. The most widespread management practice in CREP is reseeding former arable land with grasses, which it is hoped will help to reverse the rapid and sustained declines of grassland birds noted in Pennsylvania over the last 40 years. The State must provide 20% of the costs and is also responsible for monitoring the effectiveness of the habitat improvements on water quality and targeted wildlife populations.

To monitor the effects of CREP on grassland and other farmland birds in the 20 Chesapeake Watershed counties, a monitoring program was initiated in 2001. Although CREP was expanded to 23 Upper Chesapeake BAY watershed counties of Pennsylvania in 2003 and 16 counties in the Ohio River watershed in 2004. There are, as yet, no specific programs to monitor the effects of CREP in those areas.

Previous research has shown that CREP fields in southern Pennsylvania support primarily generalist species such as Red-winged Blackbirds and Song Sparrows, and edge species such as Common Yellowthroats and Indigo Bunting, with lower numbers of grassland specialists, such as Grasshopper Sparrows and Eastern Meadowlark (Wentworth and Brittingham 2005). Species diversity, abundance and nest success was higher in CREP fields than in paired hayfields. It is not clear whether the positive field-scale effects demonstrated by that study are sufficient to elicit a population level response. The aims of this paper are to examine population trends of bird species within the 20 county study area, for the period 2001to 2005, to evaluate whether CREP has resulted in large-scale responses by grassland bird populations.

Methods: Bird Surveys

The survey protocol is based on The Breeding Bird Survey (Sauer & Droege 1990), with slight modifications. Birds were surveyed for 5-minutes at up to 50 point counts along a survey route. The counts are approximately 0.5 miles apart and all birds seen or heard are counted within an 820 ft (250 m) radius of each survey point. The survey routes were selected randomly within areas dominated by farmland, according to land cover data, and were not selected to coincide with CREP agreements. Survey routes are generally along township roads; major highways, where traffic noise could reduce bird detectability, are avoided. A team of 12 highly skilled birdwatchers, who were employed by the Pennsylvania Game Commission (PGC), carried out bird surveys on 90 routes, twice per season, once in May and once in June. In 2004 and 2005 only the June surveys were conducted.

Methods: Spatial Data Analysis using GIS

Spatial analysis was carried out using ArcView GIS (Ormsby et al. 2004). The sampling unit in this analysis is the survey route (n=90). The routes averaged 33.4 point counts (range 20-50), or 16.2 miles in length. This analysis is concerned with landscape-scale population changes – our definition of landscape is the area within 790ft (500m) of each survey route. Some survey routes were almost contiguous, and hence the landscapes overlapped and could not, therefore, be considered independent samples. In these cases the landscapes were combined, reducing the sample size to 84 landscapes. The landscapes averaged 2,276 acres (range 1,275-4,847). Land cover data (Myers and Bishop 1999) were used to calculate the area of each land use within each landscape. The area of farmed land was the sum of the grassland and arable land use types.

Digitized maps of CREP agreements were supplied by the Natural Resource Conservation Service (NRCS). The following CREP practices were selected for the analysis: CP01 – introduced grasses and legumes (cool-season grasses), CP02 – native grasses (warm-season and cool-season grasses), and CP21 – filter strips (grasses). Only CREP enrolled by the start of the 2005 bird-breeding season (April 2005) was included. The area of CREP was calculated using ArcView GIS and summed across each landscape. The summed CREP area for each landscape was then calculated as a percentage of the total farmland within each landscape. The average percentage of farmland enrolled in CREP grassland practices by April 2005 was 2.51, ranging from 0 (13 landscapes) to 15.4.

Methods: Analysis of Bird Count Data

The analysis presented in this paper is based on the June counts for all five years, May counts were not carried out in 2004 or 2005. Unfortunately, for 10 survey routes, data for 2004 and 2005 are not available, and hence these routes were not included in the sample, reducing the sample size to 74 landscapes.

Population trends for the years 2001 to 2005 were estimated using program TRIM (TRends and Indices for Monitoring data). TRIM is statistical software to analyze time-series of counts with missing observations using Poisson regression (Pannekoek and van Strien 2001). TRIM is useful for modeling bird count data because the Poisson error distribution copes well with large numbers of zero counts. The effects of CREP on population changes at the landscape scale was investigated by including the percentage of farmland enrolled in CREP as a covariate. Landscapes were categorized as high CREP (>4% of farmland enrolled), medium CREP (2-4%) low CREP (0.5-2%) and none/negligible (<0.5%). Analysis was restricted to species for which TRIM was able to calculate population indices for each of the 4 CREP covariate categories, the 56 most common and widespread bird species in the 20 county study area. The list of bird species includes grassland obligates, farmland generalists and many species that are not associated with grassland (Table 1).

Results

Twenty-seven of the 56 species showed significant population changes across the study area between 2001 and 2005 (Table 1), with increases (15 species) slightly outnumbering decreases (12 species). Of the species most closely tied to grassland habitats, Ring-necked Pheasant and American Kestrel declined significantly, while Horned Lark, Red-winged Blackbird and Eastern Meadowlark increased significantly. All five of these

species have been previously in steady decline in Pennsylvania since at least the 1960s (Sauer et al. 2005).

Significant ($p<0.05$) positive effects of the amount of CREP in the landscape were detected for six species (Table 1, **bold face**). Of these, one, Gray Catbird, may be a spurious association, because this species nests and forages in scrub and woodland edges, and is unlikely to benefit significantly from CREP. No significant negative effects of CREP were detected for any bird species. Population trends are presented for nine grassland-associated species that showed a positive CREP effect at a reduced level of significance ($p<0.1$). For all of these species, populations fared better in landscapes with grassland CREP, and for most of them, fared the best in areas with at least 4% of farmland in CREP. The strongest evidence for CREP having a positive effect on population trends at the landscape scale was for American Kestrel (Figure 2a) and Eastern Meadowlark (Figure 2b), both of which increased strongly in landscapes with the most CREP. Both Song Sparrow (Figure 2b) and Grasshopper Sparrow (Figure 2f) also show positive population trends in areas with CREP. For Grasshopper Sparrow, the small number of birds detected may have prevented the result from achieving statistical significance due to large standard errors. Wentworth et al. (2006) found that Red-winged Blackbird was the most numerous nesting species in CREP in southern Pennsylvania. Our data show that this species appears to have increased in all areas between 2001 and 2004 – with the most rapid increase in areas with the most CREP (Figure 2h). However, a large population decrease between 2004 and 2005, possibly the result of a poor breeding season during the wet spring of 2004, makes it difficult to ascertain the effects of CREP on populations of this species. Mourning Dove (Figure 2b), Eastern Kingbird (Figure 2c), European Starling (Figure 2d) and Common Grackle (Figure 2e) are all species that forage in grassland, and appear to have increased in landscapes with the most CREP, while showing little population change in areas with little or no CREP.

Discussion

Although many studies have shown that grassland birds utilize CRP, often at higher species diversity and abundances than in agricultural grasslands (Best et al. 1998; Ryan et al. 1998; Weber et al. 2002), few studies have been able to demonstrate that this has produced a positive effect at the population scale (Murphy et al. 2003). We believe ours is the first study to examine the effects of CREP on bird population responses at a large-scale. That we are able to show significant population increase for several species in landscapes with the most CREP is a very significant finding. The very strong positive effect for American Kestrel and Eastern Meadowlark are especially surprising, given that the program is still in it infancy. Many of the CREP fields in the study area had been sown for only one or two years by the end of our 5-year study period, and hence the findings must be treated with some caution. It could be that we have significantly under-estimating the value of CREP for grassland birds, given that we have such a short time period with which to demonstrate population level responses. We recommend that monitoring continues, such that effects over a long time period can be assessed.

This paper presents only preliminary population level results based on the monitoring data from southern Pennsylvania. Future analyses will look at other factors that may have affected the responses, such as topography, surrounding land use, size and spatial configuration of CREP fields, and the presence of source populations to colonize them. The latter could be especially important because most of the grassland species that it is hoped

would benefit from CREP have become very localized in southern Pennsylvania (Brauning 1992). A lack of source populations to colonize the new grasslands created under CREP could result in a lag of several years between the creation of the habitat, and bird population responses.

We conclude that early evidence suggest that some grassland bird species have already benefited from the creation of grassland fields through the CREP in southern Pennsylvania. However, longer term monitoring will be needed to see whether these responses elicit a reversal of the long-term decrease in population levels of these species at a larger scale.

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Table 1. Population trends for 56 common bird species in Southern Pennsylvania between 2001 and 2005. The CREP effect is the significance of the amount of CREP in the landscape as a covariate with population trend. Species in square brackets are those considered unlikely to be significantly affected by CREP.

	Population change		CREP effect
	slope	trend/significance	p-value
Canada Goose *Branta Canadensis*	+0.0230	uncertain	0.1239
Mallard *Anas platyrhynchos*	0.0911	uncertain	0.1972
Ring-necked pheasant *Phasianus colchicus*	-0.0341	uncertain	0.4935
American Kestrel *Falco sparverius*	-0.0801	decline (p<0.01)	**0.0096****
Killdeer *Charadrius vociferous*	-0.0601	decline (p<0.01)	0.4790
Rock Pigeon *Columbia livia*	-0.0102	uncertain	0.1426
Mourning Dove *Zenaida macroura*	0.0857	increase (p<0.01)	**0.0153***
Chimney Swift *Chaetura pelagica*	0.0792	uncertain	0.4915
[Red-bellied Woodpecker *Melanerpes*	0.0866	increase (p<0.01)	0.2821
[Downy Woodpecker *Picoides pubescens*]	0.0295	uncertain	0.4344
[Northern Flicker *Colaptes auratus*]	0.0004	uncertain	0.4919
[Eastern Wood Peewee *Contopus virens*]	-0.0580	uncertain	0.1609
[Willow Flycatcher *Empidonax trailii*]	0.0103	Uncertain	0.8008
[Eastern Phoebe *Sayornis phoebe*]	-0.0085	uncertain	0.8930
[Great Crested Flycatcher *Myiarchus crinitus*]	-0.0665	uncertain	0.0661
Eastern Kingbird *Tyrannus tyrannus*	-0.0190	uncertain	**0.0352***
[Red-eyed Vireo *Vireo olivaceus*]	0.0569	uncertain	0.7278
[Blue Jay *Cyanocitta cristata*]	-0.0532	decline (p<0.01)	0.0791
American Crow *Corvus brachyrhychos*	-0.0934	decline (p<0.01)	0.0845
Horned Lark *Eremophila alpestris*	0.0798	increase (p<0.05)	0.4525
Tree Swallow *Tachycineta bicolor*	0.1455	increase (p<0.05)	0.0671
Barn Swallow *Hirundo rustica*	0.0616	increase (p<0.01)	0.3382
[Black-capped Chickadee *Poecile carolinensis*]	0.1342	increase (p<0.01)	0.0567
[Tufted Titmouse *Baeolophus bicolor*]	-0.0580	uncertain	0.6900
[White-breasted Nuthatch *Sitta carolinensis*]	-0.1269	decline (p<0.05)	0.7367
[Carolina Wren *Thryothorus ludovicianus*]	0.0657	increase (p<0.01)	0.2490
[House Wren *Troglodytes aedon*]	0.0316	uncertain	0.4809
Eastern Bluebird *Sialia sialis*	-0.1045	decline (p<0.05)	0.2261
[Wood Thrush *Hylocichla mustelina*]	0.0058	Stable	0.1212
American Robin *Turdus migratorius*	0.0543	decline (p<0.01)	0.1204
[Gray Catbird *Dumetalla carolinensis*]	0.0336	increase (p<0.05)	**0.0009***
[Northern Mockingbird *Mimus polyglottos*]	-0.0129	Stable	0.7726
[Brown Thrasher *Toxostoma rufum*]	0.1748	increase (p<0.01)	0.1131
European Starling *Sturnus vulgaris*	0.0089	uncertain	**0.0218***

Table 1 (cont'd.)

	Population change		CREP effect
	slope	trend/significance	p-value
[Yellow Warbler *Dendroica petechia*]	0.1188	Increase ($p<0.01$)	0.3317
[Ovenbird *Seiuris aurocapilla*]	-0.0739	decline ($p<0.01$)	0.0857
Common Yellowthroat *Geothlypis trichas*	-0.0036	Stable	0.3693
[Scarlet Tanager *Piranga olicacea*]	0.1594	Increase ($p<0.01$)	0.8070
[Eastern Towhee *Pipil erythrophthalmus*]	-0.0520	uncertain	0.2140
Chipping Sparrow *Spizella passerina*	0.0438	Increase ($p<0.01$)	0.1075
Field Sparrow *Spizella pusilla*	-0.0628	decline ($p<0.01$)	0.3651
Vesper Sparrow *Pooecetes gramineus*	-0.0233	uncertain	0.6914
Savannah Sparrow *Passerclus*	-0.0248	uncertain	0.7835
Grasshopper Sparrow *Ammodramus*	-0.0162	uncertain	0.1136
Song Sparrow *Melospiza melodia*	0.0192	Stable	**0.0415***
[Northern Cardinal *Cardinalis cardinalis*]	0.0138	Stable	0.9835
Indigo Bunting *Passerina cyanea*	-0.0208	uncertain	0.9411
Bobolink *Dolichonyx oryzivorus*	-0.0271	uncertain	0.3785
Red-winged Blackbird *Agelaius phoeniceus*	0.0439	Increase ($p<0.01$)	0.0863
Eastern Meadowlark *Sturnella magna*	0.0541	Increase ($p<0.05$)	**0.0168***
Common Grackle *Quiscalus quiscula*	0.0138	Stable	0.0757
Brown-headed Cowbird *Molothrus ater*	0.0479	uncertain	0.6028
[Baltimore Oriole *Icterus galbula*]	0.0688	uncertain	0.9779
[House Finch *Carpodacus mexicanus*]	-0.1074	decline ($P<0.05$)	0.9715
American Goldfinch *Carduelis tristis*	-0.1005	decline ($p<0.01$)	0.5745
[House Sparrow *Passer domesticus*]	0.0096	Stable	0.9562

Figure 1. Map of the 20 county study area –shaded white, and sampling areas (landscapes) – shaded black.

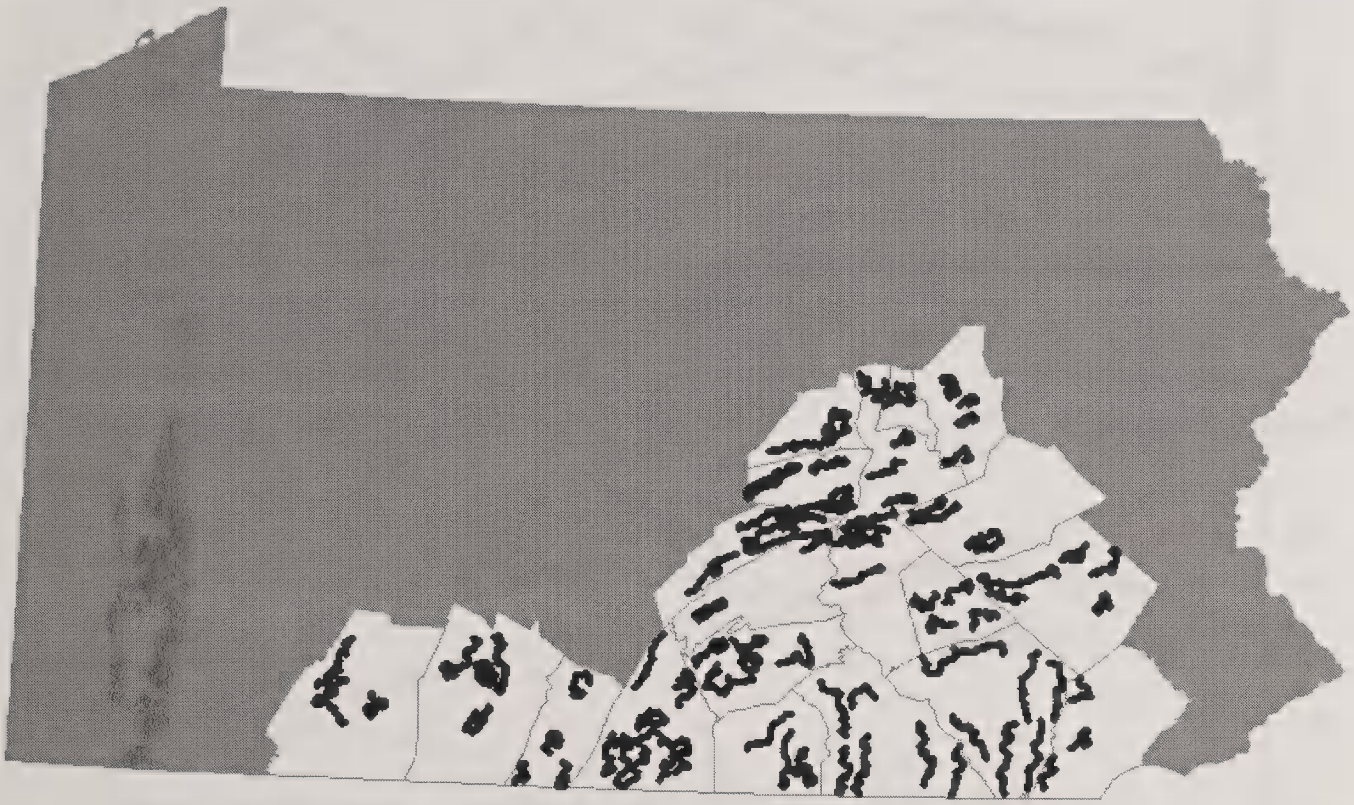
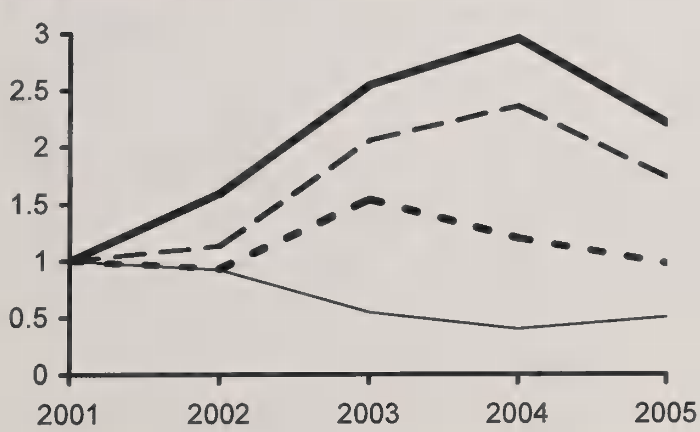
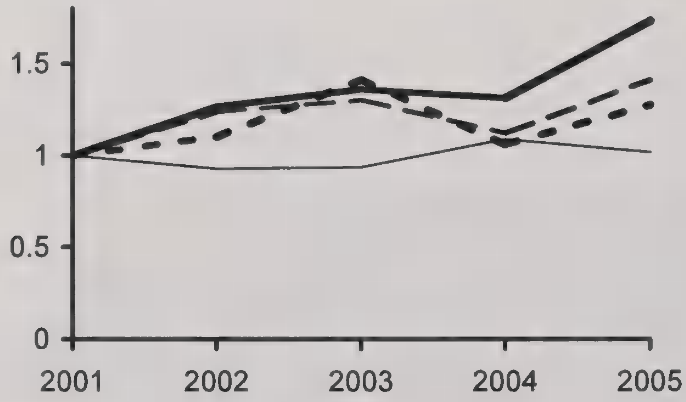


Figure 2. Population trends for grassland associated species that show a significant effect of CREP, in southern Pennsylvania during the period 2001 to 2005. Bold solid line=high CREP areas (>4% of farmland in CREP), dashed=medium CREP (2-4%), dotted=low CREP (0.5-2%), light solid no CREP (<0.5%). The y-axis is the population index, relative to an index value of 1 in 2001, hence a value of 0.5 represents a halving of populations levels, while an index value of 2 represents a doubling.

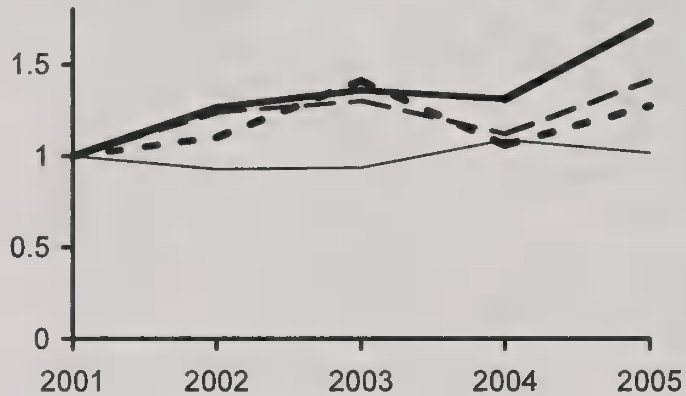
2a. American Kestrel



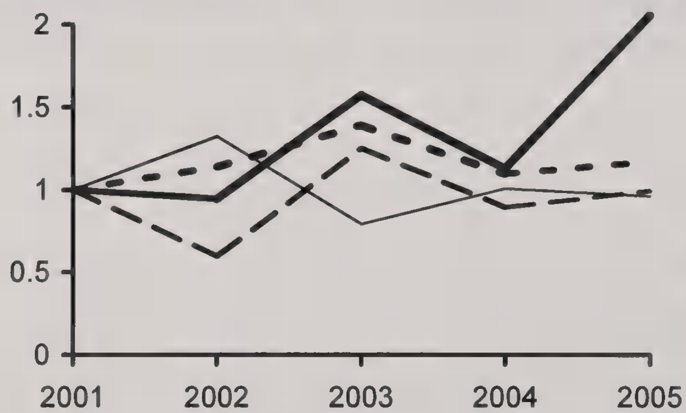
2b. Mourning Dove



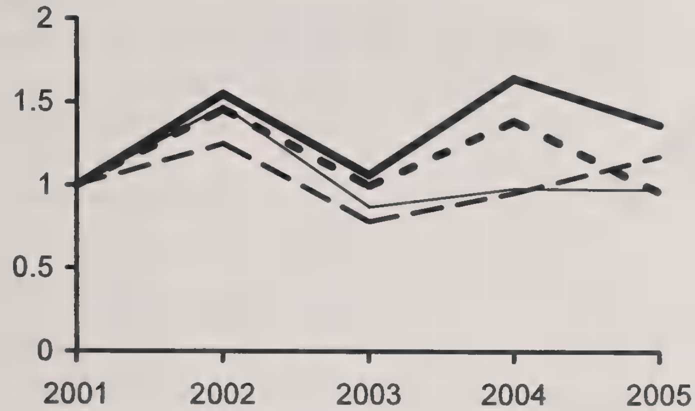
2c. Eastern Kingbird



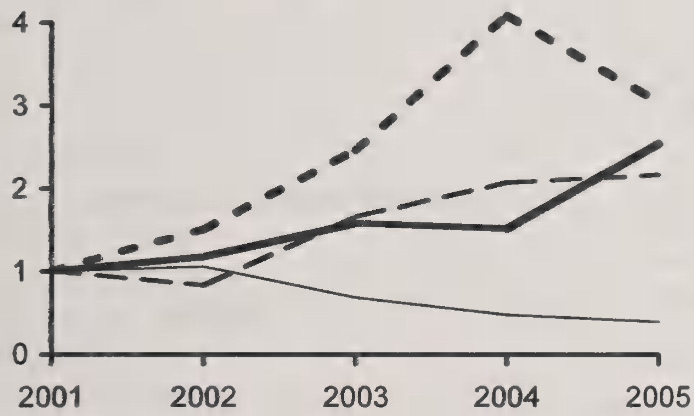
2d. European Starling



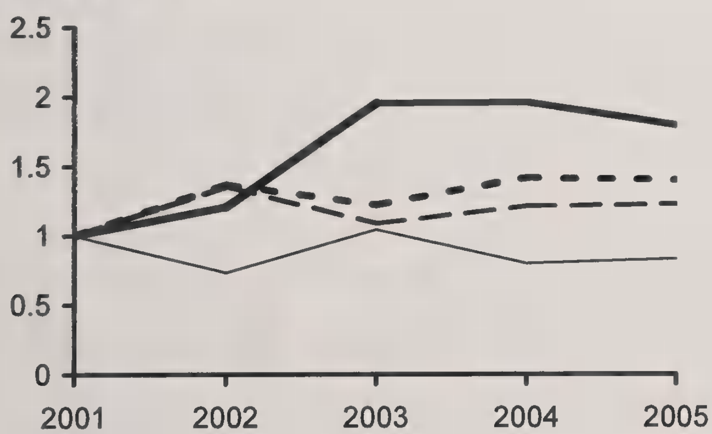
2e. Common Grackle



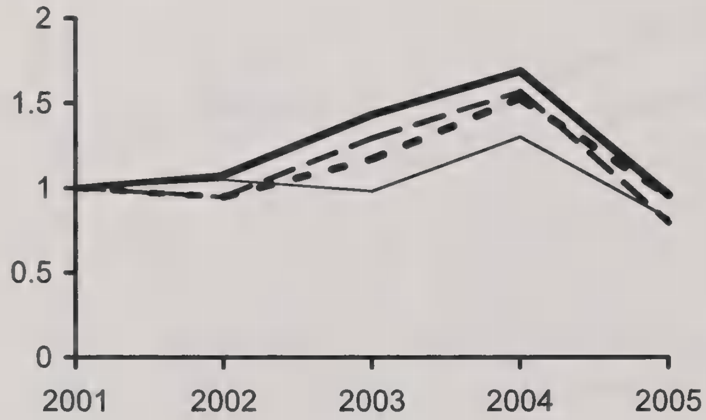
2f. Grasshopper Sparrow



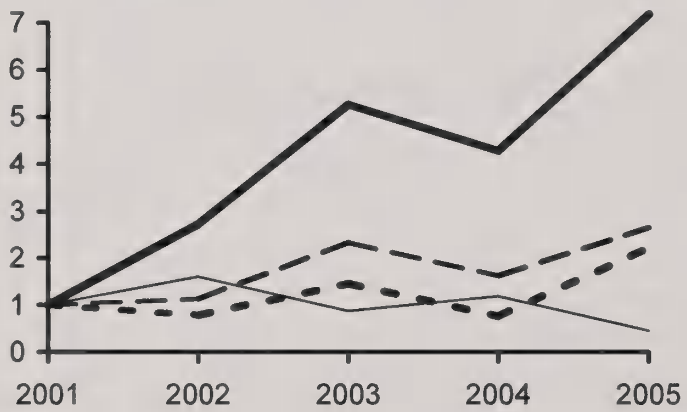
2g. Song Sparrow



2h. Red-winged Blackbird



2i. Eastern Meadowlark



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